PROCEEDINGS
OF THE
NATIONAL ACADEMY OF SCIENCES

Volume 10 JULY 15, 1924 Number 7

HISTORICAL TRADITION AND ORIENTAL RESEARCH

By James Henry Breasted

University of Chicago

Read before the Academy, April 29, 1924

It has often been remarked that the outstanding trait of the untrained mind is credulity. The rationalization of man's views of the world has been a very slow process and it is still very far from a completed process. It has commonly been thought to have begun with the Greeks, but its origin must be sought in the Orient in a period long before Greek civilization had arisen. The Edwin Smith Medical Papyrus, acquired in 1906 by the New York Historical Society, discloses the inductive process of scientific investigation already in operation in the Seventeenth Century before Christ. For example this document contains the earliest occurrence of the word "brain" anywhere appearing in surviving records of the past. The word is unknown in Old Testament Hebrew, in Babylonian, Assyrian, or any of the ancient languages of Western Asia. The organ itself therefore, was evidently discovered and the recognition of its various functions was begun for the first time by these physicians of early Egypt in the thousand years preceding the Seventeenth Century B. C. The observations recorded in the Edwin Smith Medical Papyrus show that its author had already observed that control of the members and limbs of the body was localized in different sides of the brain; and the recognition of localization of functions in the brain, mostly the work of modern surgeons within a generation or two, had already begun in the Seventeenth Century B. C., at a time when all Europe still lay in savagery or barbarism.

I hold in my hand part of an original transit instrument, made as stated by the inscription upon it, by no less a king than Tutenkhamon, in the Fourteenth Century B. C. *It did not come from the tomb of Tutenkhamon*, but was apparently made by him for the tomb of his (or his wife's) great-grandfather, Thutmose IV (Fifteenth Century B. C.). This and another such piece now at Berlin, are the oldest scientific instruments of any kind now known to be surviving. It was used for determining meridian time, especially at night, in order that the observer might then set his water

clock, with its 24-hour divisions,—a division of the day which thence passed over into Europe in Hellenistic times, whence it was transmitted to us.

Now Herodotus reports a tradition current in his day (Fifth Century B. C.), that the Greeks were greatly indebted to Egyptian knowledge. This tradition has in recent times been universally rejected; but the documents submitted here today may serve at least to illustrate the fact that there was much truth in the tradition transmitted to us by Herodotus, and that its complete rejection by classical prejudice is unjustifiable.

The fact that the early Egyptian scientist employed an inductive method as far back as the Seventeenth Century B. C. does not, however, mean that he had completely banished from his mind all belief in magic or in supernatural forces. This truth has been well demonstrated for later ages by Prof. Lynn Thorndyke in his monumental two volumes on the History of Magic and Experimental Science—a work of which America may well be proud. Undoubtedly the Greek took the longest step in freeing his mind from inherited religious and traditional prepossessions. Using astronomical observations undoubtedly drawn from Babylonia, Thales predicted a solar eclipse in 585 B. C. Astonishing as it seemed to the Greeks, there is little probability that this feat was an unprecedented achievement. What *was* unprecedented however, was the revolutionary generalization which Thales based upon his ability to make such a prediction. *For he banished the erratic whims of the gods from the skies and discerned the sway of natural law throughout the celestial world.* To tear away and fearlessly to trample under foot beliefs and superstitions which had been sanctified by age-long religious veneration demanded dauntless loyalty to his own intelligence. This first supreme enthronement of the human mind, was probably the greatest achievement in the career of man.

We can pay no greater tribute to such Greek thinkers than to recognize, that although they put credulity to rout, they could not banish it altogether. It has survived with extraordinary persistence even to the present day, and in the person of a distinguished statesman who once occupied high office in this city, its rampant assertiveness furnishes a complete physiological demonstration that the organs of speech in the human animal may function perfectly and sometimes with extraordinary copiousness in complete disconnection from the processes of cerebration.

In modern times it was of course the tremendous significance of the discoveries of Galileo which most impressively reproclaimed the supremacy of natural law and the sovereignty of the human mind in discerning that law. In this new home of science which we are now dedicating, there is nothing which more nobly illustrates its high mission than the dramatic power with which Lawrie's immortal bronze discloses the simple and dauntless figure of Galileo confronting theological dogma with the majestic facts of the universe.

From Galileo's struggle with the church to Huxley's debate with Gladstone, the heavy guns of Natural Science have dealt tradition one destructive blow after another. It has been under this destructive attack at the hands of Natural Science that historical criticism has grown up in modern times since Niebuhr. Indeed it has been no accident that in our own country the first serious discussion of the Old Testament narratives in Genesis and Exodus, was written by *Thomas Cooper*, who was the associate of Priestley in the discovery of oxygen. Cooper was Thomas Jefferson's appointee as first president of the new University of Virginia; but in the Virginia of that period the social feeling against Cooper for having assailed the literalistic interpretation of the Old Testament, was so strong that Jefferson was unable to secure his induction into office. Jefferson's influence however, secured Cooper's appointment as president of the University of South Carolina, where public opinion was at first not so strong against him as in Virginia. It is interesting to note that before the end of the twenties, that is less than a century ago, conservative sentiment was strong enough to bring about Cooper's dismissal from the university, although his personal popularity was such that he was promptly appointed to codify the laws of the state, and the first legal code of the State of South Carolina was edited by this gifted representative of Natural Science and Historical Criticism.

The merciless critical scalpel which had not spared Hebrew tradition was equally unsparing in its treatment of the cherished classical heritage from Greece and Rome. The tales of Romulus and Remus, the Trojan war and the entire cycle of legends which were linked with it, were shorn away. A critical attitude of universal negation arose. It included the whole Mediterranean and Oriental World: Rome, Greece, Hebrews, Babylonians, Assyrians and Egyptians. Historical criticism would not allow that early man at the beginning of the age of writing had ever heard and transmitted an echo from earlier ages, which, because they possessed no writing, could only send on their story in the form of oral traditions. This attitude of the historical critic may be compared with that of an observer who stands on a mountain peak, and looking off across a distant landscape to a dim horizon shrouded in mists and cloud, insists that the intermittent glimpses of mountain profiles which vaguely emerge on the far-away skyline cannot correspond to any reality. In short without ever having been himself on the ground to investigate, he denies the existence of the phantom mountains on the horizon.

The orientalist, if he be something more than a philologist, may be compared with the explorer who pushes out to that distant horizon, and is able to determine on the ground whether the phantom mountains really exist. Such investigation is however, relatively recent and the historical critic could hardly anticipate that it was coming. He seemed to be quite

safe in sweeping away all early human tradition. It dealt with a world of gods, demi-gods and heroes; it was dominated by the whims and caprices of angry or jealous divinities, and it was filled with impossible wonders and prodigies. How could a soundly critical historian accept narratives which seemed so manifestly impossible? We must grant that under the circumstances rejection complete and unqualified seemed the only safe course.

Such critical negation was supreme when fifty years ago archaeology began to reveal with startling vividness the facts and the daily equipment of human life in the very ages with which the rejected traditions dealt. In the seventies of last century the excavations of an untrained observer from the outside disclosed an astonishing vision of pre-Greek civilization at Tiryns, Mycenae and Troy. The incredulity with which these discoveries of Heinrich Schliemann were greeted by the classicists was highly characteristic. His excavations recovered and exhibited to the incredulous eyes of the destructive critics the whole material equipment of daily life from the very age of the Trojan war (or wars), and from the very city in and around which that war was waged.

Similar revelations, involving far earlier periods of time, rapidly disclosed the successive stages of the human career from a remote antiquity, reaching well back of the beginnings of the world as dated by an alleged "Biblical" chronology. In dealing with the traditions of these earlier ages, the orientalists soon developed a similar school of negative criticism. Such traditional accounts were promptly thrown into the discard. Maspero's bulky history of the oriental peoples still a standard work on most modern library shelves, tells us that Menes the first king of the First Dynasty of Egypt, was a purely mythical or legendary figure. Nevertheless we now possess his tomb, and in our collections at the University of Chicago, we have a piece of his personal ornaments, a gold bar bearing his name in hieroglyphic,—the oldest piece of inscribed jewelry in existence. Since 1894 thousands of prehistoric graves have been excavated along the margin of the Nile Valley, revealing to us the successive stages of human advance for many centuries before the once legendary Menes.

Much the same process is going on in the investigation of Babylonian history. Even the mythical hero Gilgamesh, the original of the European Hercules, bids fair to emerge at last as a remote city king of early Babylonia, who gained a reputation for his prowess in war till he became the typical and proverbial strong man of all ages.

The crowning disclosure in this unprecedented series of unexpected revelations has just come from Asia Minor. Nearly twenty years ago the German Assyriologist Hugo Winckler visited the mounds of Boghaz (or Boghaz Köi—"Boghaz village") in central Asia Minor. As he walked over the ruins he kicked up with his boot heel several cuneiform tablets, lying practically on the surface. Below were piled the clay tablet archives

of the Hittite Foreign Office the earliest of which had been lying here at the capital of the Hittite Empire since the middle of the second thousand years before Christ. The result has been the decipherment of ancient Hittite or rather a whole group of Hittite dialects. The Great War has intervened and since Winckler's death the progress of examining this enormous body of archives has unavoidably been very slow. We owe a great debt especially to Hrozny and Forrer for the invaluable disclosures which they have wrung from these documents.

One of these tablets reports a *war of Atreus, king of Achaia against the king of Caria* at about the middle of the thirteenth century, that is about 1250 B. C. There can be no doubt that in this tablet we have a contemporary reference to the cycle of Trojan wars,—a reference which must be regarded as an irreproachable historical source, as old as the events which it records. Thus out of the lost oriental background of Greek history in Asia Minor comes a *written* document confirming a Greek tradition, born in an age when the Greeks themselves still lacked writing. Because writing reaches further back in the orient by nearly three thousand years than it does in Greece, we are therefore able to confirm Greek tradition out of contemporary written sources.

It has long been recognized that in the early development of Greek civilization the cities of Asia Minor took the lead. Thales, who lived in one of these cities was an example of this early stage of Greek culture in Asia Minor. It is also evident that the inland background of oriental culture contributed much to this early development of Greek civilization on the western fringes of Asia. It is out of this newly recovered oriental background that we are slowly regaining the earlier forerunners of Greek civilization.

This contemporary reference to the Trojan war is an epoch-making revelation, which must react powerfully upon our treatment of early human traditions. It at once demonstrates that such traditions must not be thrown to the scrap heap, but rather carefully divested of gods and goddeses, prodigies and wonders, and then examined for the nucleus of sober fact upon which the legendary tale has been built up.

As we look back upon our earliest historical horizon, we now know that the men who stood there in the gray dawn of the age of writing, were able to hear echoes of a remoter past, transmitted in the form of oral tradition of which some portion was then committed to writing and thus survived. In our modern effort to recover and reconstruct the story of man's past career, we have thus rehabilitated a new body of sources, however cautious it behooves us to be, in making use of them. Not credulity, but historical method demands that we now recognize these traditions, or the nucleus of fact to be drawn from them, as a body of sources now to be restored to their proper chronological position in the succession of surviving evidences which reveal to us the past career of man on earth.

We are the first generation of men able to survey that career without a serious break. As we marshal the evidence for its successive stages we humanists stand shoulder to shoulder with the natural scientists; for as we look backward it is the materials and the methods of the geologist which confront us first. The geologist is succeeded by the palaeontologist, the anthropologist, the anthropogeographer and the archaeologist. It is at this point, on the border land between the investigations of the natural scientist and those of the humanist that we must insert these long discarded echoes from an age able to transmit only oral tradition, the true value of which oriental research has now interpreted to us. The Homeric songs of the Trojan War can no longer be regarded as exclusively noble literature, of purely legendary content, and in the presence of these earliest surviving monuments of science the Greek tradition of substantial Egyptian contributions to knowledge must not be rejected as baseless. There is every possibility that the tombs of Egypt may yield us further scientific treatises like this great Edwin Smith Medical Papyrus, and we still cherish the hope that the thirty-five or forty chests, boxes, and caskets still lying in the innermost chamber of the tomb of Tutenkhamon with their seals unbroken, may contain written documents.

SECOND NOTE
ELECTRODYNAMICS IN THE GENERAL RELATIVITY THEORY.

By G. Y. Rainich

Department of Mathematics, Johns Hopkins University

Communicated May 8, 1924

In the preceding note[1] it was indicated that in a region not containing matter but containing an electromagnetic field the contracted curvature tensor F must satisfy certain conditions and it was stated that if these conditions are fulfilled an antisymmetrical tensor which satisfies the energy relation and the Maxwell equations can be found. We shall now push the mathematical discussion a little farther and indicate in what direction the results can be interpreted physically.

1. The conditions to which F is subjected were given in a geometric form; although we are not going to here make use of the expressions of these conditions in coördinates it may be of some interest to write down these expressions. The *algebraic* conditions which are a consequence of the antisymmetry of the electromagnetic tensor, may be easily found in writing that $F^2(x)$ is a function which without changing the direction of any vector multiplies the length of every vector by ω^4, ω^2 being equal to $\frac{1}{2}(\mu^2-\lambda^2)$,

and that the sum of the roots of the secular equation is zero; we have thus

$$F^\sigma_i F^j_\sigma = \delta^j_i \omega^4 \tag{9}$$

and

$$F^\sigma_\sigma = 0; \tag{10}$$

there are five independent among these relations (which, it may be noted, follow from three relations among the roots of the secular equation) so that only *five* out of the ten coefficients F^j_i are independent.

As to the *differential* conditions, we saw that beside the known equations $F^\sigma_{i,\sigma} = 0$ which are a consequence of the Bianchi equations, some equations must hold which give expression to the fact that a certain vector q is a gradient of a scalar function. To express this condition in coördinates we may introduce a completely alternating tensor of the third rank q_{ijk} (which is essentially the vector q) with the aid of the equation

$$q_{ijk}.\omega^2 = (g_{\sigma i} F^\tau_{j,k} + g_{\sigma j}.F^\tau_{k,i} + g_{\sigma k}.F^\tau_{i,j})F^\sigma_\tau \tag{11}$$

where we use Greek indices to indicate summation. Our equation which expresses that q is a gradient can now be written as

$$q^\tau_{ij,\tau} = 0. \tag{12}$$

2. If the conditions (9), (10) are satisfied it is possible to find an antisymmetrical tensor which satisfies the energy relation. But *this tensor is not unique:* if f is a tensor which, together with its dual d satisfies the relation (6) of the first note[1] then the tensor

$$\xi f + \eta d \quad \text{with its dual} \quad \eta f + \xi d \tag{13}$$

also satisfies the same relation, when $\xi^2 - \eta^2 = 1$, as can be readily seen by substituting the expressions (13) for f and d in (6). As ξ is here a real quantity and η is purely imaginary it is suggested to put

$$\xi = \cos\varphi \qquad \eta = \sqrt{-1}.\sin\varphi \tag{14}$$

If we want now to express the condition that (13) satisfy the Maxwell equations we obtain the result that this condition is *that the gradient of φ be equal to the vector q*, the vector whose ability to be a gradient is assured by the equations (12).

3. Before we pass to the question of interpretation of these results it is useful to mention that the formal part of this discussion—put aside the geometric significance in terms of general relativity theory—can be translated in terms of classical electrodynamics. We consider instead of the electromagnetic tensor the electric and magnetic force vectors E and H, and instead of the contracted curvature tensor the Maxwellian stress

components p_{ij}. These components are simple combinations of the quantities

$$\begin{matrix} E_x^2 + H_x^2, & E_y^2 + H_y^2, & E_z^2 + H_z^2, \\ E_yE_z + H_yH_z, & E_zE_x + H_zH_x, & E_xE_y + H_xH_y \end{matrix} \tag{15}$$

and the components of the Poynting vector and the electromagnetic energy which together with the p_{ij} make out the components of the relativistic energy tensor, are easily seen to be algebraically derivable from the stress components—this corresponds to four of the relations among the F_i^j, the fifth being a relation of the third degree which must be satisfied by the p_{ij} themselves.

If we suppose now that the stress components are given and that E and H are an electric and magnetic vector which produce these stresses we can verify by direct substitution that the vectors

$$E\cos\varphi - H\sin\varphi \quad \text{and} \quad E\sin\varphi + H\cos\varphi \tag{16}$$

would give the same components (and, of course, the same Poynting vector and the same energy), φ being an arbitrary quantity. If we now subject the vectors (16) to the 8 Maxwell equations we obtain four pairs of equations of the form $A\cos\varphi - B\sin\varphi = 0$, $A\sin\varphi + B\cos\varphi = 0$, where the A's and the B's contain linearly the components of E, H, their derivatives and the derivatives of φ. We see immediately that $\cos\varphi$ and $\sin\varphi$ drop out from our equations and there remain 8 equations which, on the one hand, lead to differential relations for the stress components corresponding to the equation (12) and, on the other hand, permit us to find the values of the derivatives of φ—that is the gradient of φ—in accordance with the results stated in Section 2, unless we have simultaneously $E_xH_x + E_yH_y + E_zH_z = 0$ and $E_x^2 + E_y^2 + E_z^2 = H_x^2 + H_y^2 + H_z^2$, i.e., in all cases with the exception of the case of a self-conjugate field[2]—this corresponds to $\omega^2 = 0$.

4. We return now to the point of view of the general relativity theory; it is only here that our results acquire their full significance because the tensor F is here defined by the space-time; we can, therefore, say that if the structure of space-time is given the electromagnetic tensor is practically given the only remaining arbitrariness being the initial value of φ (since the derivatives of φ can be found) and, at least in some cases, this initial value seems to be of no importance so that everything is given by the geometry.

In order to find a physical interpretation for the above results we consider the case when in a certain three-dimensional space (forming part of our space-time) the time derivative of φ is constant for a certain point during a certain time and equals, say k; if then we denote the value of

φ at the moment $t = 0$ by φ_0, the electric and magnetic forces at the point considered will be given by

$$E\cos(\varphi_0 + kt) - H\sin(\varphi_0 + kt),\quad E\sin(\varphi_0 + kt) + H\cos(\varphi_0 + kt) \quad (17)$$

where the vectors E and H and the number k are given by the structure of the space-time; we see that the electric and magnetic forces are periodic and that this periodicity is the necessary consequence of the properties of space-time; since distribution and movement of matter can be considered as properties of space-time we see in what way periodic electromagnetic fields (radiation) can be produced by material processes. This seems to indicate that non-periodic material processes can be considered as sources of oscillations.[3] As a matter of fact we may consider in such a case the periodicity as a fiction, as a mathematical device only, suggested by the fact that we have to consider two quantities the sum of whose squares is unity, but the notion of a *period* and consequently of a *wave-length* are "realities" and the values of these quantities are determined by the structure of space-time. If q varies slowly we have radiation of variable wave-length or non-monochromatic radiation. Perhaps the consideration of the vector q is a more convenient starting point in the theory of radiation than the considerations connected with the transport of energy; the latter being of a non-invariant character.

5. The question of superposition of two radiations cannot be treated or even correctly put along the classical lines as long as we remain in regions with strong electromagnetic fields on account of the non-linearity of the equations which determine the field (comp. section 2 of the first note;[1] the non-linearity of our system of equations is also brought out by the form of the equations (9) and (11)). The vector q seems also to be better adapted to the study of monochromatic radiations. But at a large distance from the "sources" of radiation we can use the approximation which consists in neglecting the curvature and results in the linearity of our equations; this approximation leads to the classical theory of superposition and it is significant that as we recede from the sources the field tends to become self-conjugate[4] and that just in this case the vector q becomes indefinite.

6. The general equations cannot give us an answer to the question whether q has a time direction, a space direction, or a zero direction. Consider the case of its being a space vector. Then it is possible by choosing our space to eliminate radiation which is present in the same world-point from the point of view of other spaces; with other words there exists an observer for whom there is no radiation where there is radiation for other observers; and since for some of these other observers k will be positive and for some—negative it seems possible that what is absorption for one space will be emission for another. A more detailed study of all

these questions requires however the consideration of singularities of the field.

[1] These PROCEEDINGS, **10**, No. 4, April, 1924.

[2] Comp. H. Bateman, *Electrical and Optical Wave-Motion*, Cambridge: 1915, p. 5.

[3] See e. g., A. Sommerfeld, *Atomic Structure and Spectral Lines*, English Translation, p. 29.

[4] Bateman, *l. c.*, p. 9.

THE REFLECTION OF CHARACTERISTIC BROMINE X-RADIATION BY A CRYSTAL OF POTASSIUM BROMIDE

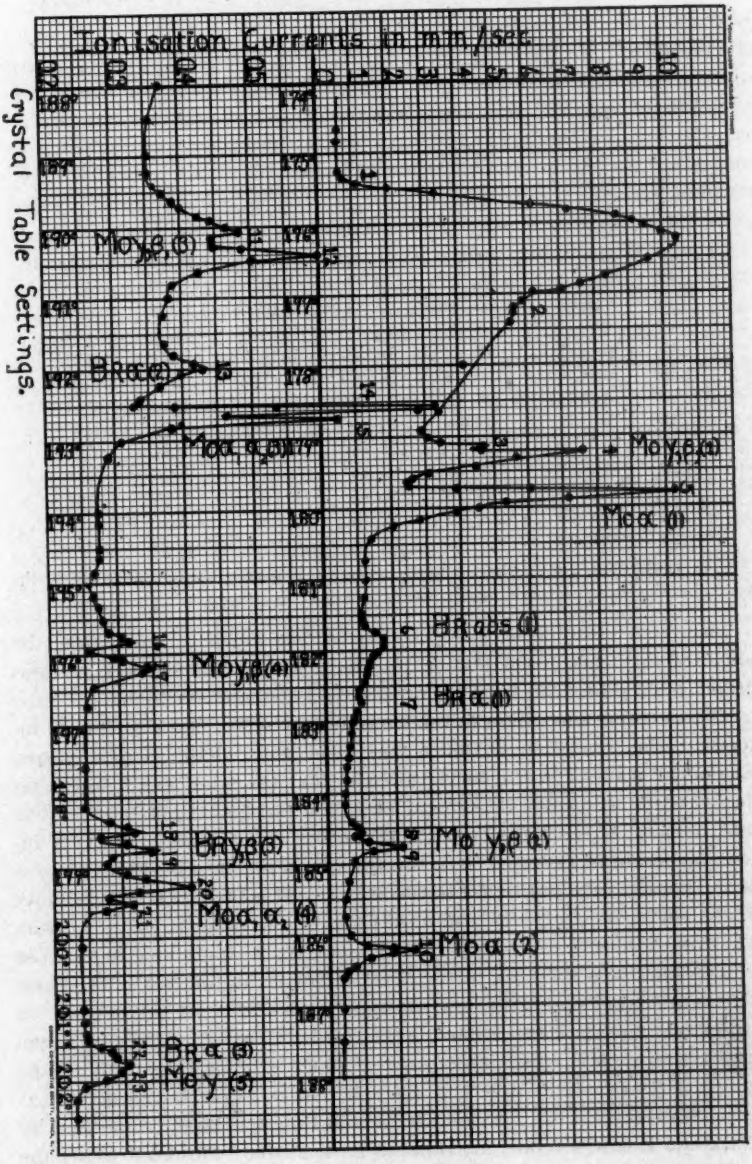
BY S. K. ALLISON[1] AND WILLIAM DUANE

In previous numbers of these PROCEEDINGS[2] Clark and Duane have published accounts of experiments in which X-ray spectra have been obtained by reflection of general and characteristic X-radiation from crystals of certain alkali halides and polyhalides containing iodine and cesium. They found that when the voltage on the X-ray tube was sufficient to produce a wave-length shorter than the K critical absorption wave-length of these elements, in addition to the spectrum of the general radiation and line spectrum of the target, diffuse peaks appeared at angles at which the K series radiation characteristic of the elements in the crystal should be reflected according to the Bragg law. They have discussed some of the peculiar properties of this radiation.

In the experiments reported here we have examined the spectrum produced by the reflection of X-radiation from a molybdenum target tube by the 100 planes of a crystal of potassium bromide, using an ionization spectrometer, and have found evidence of the characteristic bromine K-series peaks. The molybdenum target tube was one especially designed for high voltage and was operated at 63,000 volts and 2 m. a. After a few preliminary trials, a small crystal .3 mm. thick and with 1.3 × 2.5 mm. faces, obtained by cleavage, was selected, which gave sharp molybdenum peaks at angles agreeing quite accurately with the Bragg law. The crystal was mounted in the center of the spectrometer table with its 100 planes parallel to the axis of rotation, and the X-rays were reflected from planes perpendicular to its faces, so that both the undeviated and reflected beams were transmitted through it.

The spectrum obtained appears in the accompanying figure, and the table contains the interpretation of the discontinuities observed. Wyckoff[3] has made a determination of $2d_{100}$ for KBr and finds it to be 6.59 Å. Baxter and Wallace[4] have made a very careful determination of the density of KBr at room temperature and find it to be 2.749. This leads to a value

of d_{100} of 3.293 Å. In calculating wave-lengths in the spectrum we have used the value $d_{100} = 3.294$ Å.



INTERPRETATION OF SPECTRUM FROM KBr

$d_{100} = 3.294$ Zero setting = 173°44′

NO.	LINE	SETTING	$\theta_{OBS.}$	$n\lambda$ CALC.	λ CALC.	PREVIOUS λ
1	Limit	175°22′	1°38′	.188	.188	...
2	I ion (1)	177°0′[1]	3°16′	.375	.375	.3737
3	Moγ (1)	179°09′	5°25′	.621	.621	.6197
4	Moβ (1)	179°14′	5°30′	.6314	.6314	.6311
5	Moα (1)	179°52′	6°08′	.7038	.7038	.7078
6	Br abs (1)	181°43′	7°59′	.9149	.9149	.9179
7	Brα (1)	182°45′	9°01′	1.03	1.03	1.036
8	Moγ (2)	184°35′	10°51′	1.2402	.6201	.6197
9	Moβ (2)	184°45′	11°01′	1.2589	.6294	.6311
10	Moα (2)	186°12′	12°28′	1.4222	.7111	.7078
11	Moγ (3)	190°03′	16°19′	1.8509	.6169	.6197
12	Moβ (3)	190°26′	16°42′	1.8931	.6310	.6311
13	Brα (2)	191°58′	18°14′	2.0613	1.0306	1.036
14	Moα_1 (3)	192°36′	18°52′	2.1303	.7101	.7078
15	Moα_2 (3)	192°42′	18°58′	2.1412	.7127	.7121
16	Moγ (4)	195°49′	22°05′	2.4768	.6192	.6197
17	Moβ (4)	196°12′	22°28′	2.5176	.6294	.6311
18	Brγ (3)	198°28′	24°44′	2.7564	.9188	.914
19	Brβ (3)	198°44′	25°00′	2.7842	.9281	.929
20	Moα_1 (4)	199°15′	25°31′	2.8380	.7095	.7078
21	Moα_2 (4)	199°29′	25°45′	2.8621	.7155	.7121
22	Brα (3)	201°42′	27°58′	3.091	1.030	1.036
23	Moγ (5)	201°45′	28°01′	3.0946	.6189	.6197

[1] The slight drop due to the I critical ionization is masked in the rapid fall of the general radiation so that an accurate estimate of angle is difficult.

The "zero" reading of the spectrometer was found by calculating the angle of incidence for a number of the molybdenum peaks in various orders, subtracting this from the observed setting, and averaging.

The following discussion of the curve obtained will reveal points of interest. The ionization chamber was filled with methyl iodide vapor. At point 2 a break in the curve indicates that the wave-length of the reflected beam has passed the critical ionization wave-length of iodine. The molybdenum K series peaks in the first order at 3, 4, and 5, are very intense as would be expected since the voltage on the tube is so far in excess of the voltage required to excite this series. At 6 there is a discontinuity in the curve due to the critical absorption of the bromine in the crystal. The total intensity of radiation on the long wave-length side of this rise is somewhat less than $^1/_5$ of the total intensity at the Mo α (1) peak. This is in marked contrast to the spectra obtained from KI with a tungsten target tube by Clark and Duane in which the intensity on the long wave-length side of the iodine absorption is much greater than that of the tungsten peaks. This difference may be easily explained as due to at least two factors. (1) The voltage on the tungsten target tube used by Clark and Duane was only 1.3 times as great as that required to excite the

tungsten K series, while the voltage used in these experiments was 3.1 times the K critical molybdenum voltage. The molybdenum peaks therefore are of great intensity. (2) In the experiments of Clark and Duane the general radiation from the target was very intense in the wave-length region of the first order of the iodine spectrum, as contrasted with its feeble intensity in this experiment at wave-lengths as long as those characteristic of bromine. The iodine peaks were therefore superimposed on an intense general radiation. Walter[5] has commented upon the fact that the iodine and cesium peaks appear to be about as intense as the tungsten radiation; this is seen not to be a general property of this phenomenon.

At 7, where a wave-length corresponding to the Kα radiation of bromine should be reflected, faint evidence of the presence of this peak was repeatedly obtained. It seems to be in general true of this reflected characteristic radiation, that at smaller glancing angles of the primary beam (lower orders) the radiation is much more diffuse than at larger angles.

The second order molybdenum peaks at 8, 9, 10 are about $^1/_5$ the intensity of those in the first order, which is approximately the intensity ratio observed in spectra from other crystals.

Attention should be drawn at this point to the fact that the vertical scale for the spectra of higher orders has been greatly enlarged. The Moγ(3) peak at 11 occurs at the angle at which the Brγ and β(2) are to be expected. This makes it impossible to be sure of the presence of the Br peaks here. Undoubtedly part of the rise on the short wave-length side of the Moγ(3) is due to the second order of the bromine absorption.

At 13 the peak Brα(2) occurs, the first thoroughly satisfactory evidence of the bromine line spectrum. It is much sharper and more pronounced than the faint indication in the first order, as is characteristic of this phenomenon.

At 18 and 19 Brγ(3) and Brβ(3) are separated and quite unmistakable. This separation shows that the presence of the β peak in these characteristic reflected spectra from the crystal cannot be ascribed merely to the absorption, followed by a decline in intensity, as suggested by some authors.

At 22, 23 the molybdenum spectrum again interferes with the bromine spectrum in that Moγ(5) comes near the calculated position for Brα(3). The presence of two lines is, however, indicated by the shape and breadth of the peak.

It should be remarked that the wave-lengths of the bromine K spectrum are not known with great accuracy; the value given in tables for BrKγ is certainly too low, since it is shorter than the critical absorption wave-length of bromine as accurately determined in this laboratory. In calculating positions where the Brα peak should occur, we have used the value λ = 1.036 Å. as the weighted mean of the previously determined values of Brα_1 and Brα_2.

It should be noted that in the curve showing the higher orders, the ordinates do not begin at zero ionization current, so that the peaks are really on a rather high base level made up primarily of scattered radiation and higher orders of the reflected general radiation. This would make them very difficult to detect by a photographic method.

Recently Walter[5] has attempted to obtain photographic evidence of this phenomenon from crystals of KBr with molybdenum primary rays as in these experiments, and has reported negative results. His photographed spectra cover the first and second orders of the molybdenum K series, and the first order of the bromine absorption only. From the curve presented here it would seem almost impossible to obtain photographic evidence for the presence of Brα in the first order due to its diffuseness and the low intensity in this region. The evidence for the presence of this phenomenon in all cases comes primarily from higher orders. Other experiments will be reported by Clark and Duane which indicate that in order to obtain photographic evidence of the presence of these peaks, a narrow slit in front of the photographic plate should be used to limit the reflected beam. Such a slit is not usually employed in photographing X-ray spectra.

[1] NATIONAL RESEARCH FELLOW.
[2] These PROCEEDINGS, **9**, p. 126; **10**, p. 419 (1923).
[3] Wyckoff, *J. Wash. Acad. Sci.*, **11**, 429 (1921).
[4] Baxter and Wallace, *J. Amer. Chem. Soc.*, **38**, 259 (1916).
[5] *Zs. Physik*, **20**, 257 (1923).

QUANTITATIVE THEORY OF THE INFLUENCE ELECTROSTATIC GENERATOR

BY ALFRED W. SIMON

RYERSON PHYSICAL LABORATORY, UNIVERSITY OF CHICAGO

Communicated June 4, 1924

A rigorous quantitative theory of the influence electrostatic generator has never been given. Maxwell[1] has worked out a special case—that of the Kelvin replenisher—but his solution is only an approximation, for he has assumed that the carriers give up all their charges to the inductors, and, further, has neglected the fact that each element of the machine is influenced by all the other elements.

The author has developed a mathematical treatment, which can be applied to any static machine, and which is not subject to the criticisms mentioned above.

The method of attack consists in (1) writing the equations for the charges on the elements of the machine in terms of the potentials, the coefficients of capacity, and the coefficients of induction of the elements, for each of those configurations of a complete cycle in which a change of charge occurs on any of the elements. To these equations are added a number of others involving the charges only, and usually expressing conservation of quantity of electricity. Leakage is neglected. (2) From this basic group of equations all the charges are eliminated, and a number of simultaneous equations obtained, each of which gives the potential of a particular element at, say, the beginning of the $(n + 1)$st cycle in terms of the potentials of a certain number of the elements at the beginning of the previous, the nth, cycle. (3) From this second group of equations there is deduced a number of additional equations giving the potentials of the same elements at the beginning of the $(n + 2)$nd, $(n + 3)$d, up to the $(n + m)$th cycle. (4) From the latter set, by elimination, a final set of equations is deduced, each of which involves only the potentials of a single element over a number of successive cycles, and which is therefore of the form:

$$V_{n+m} + k_1 V_{n+m-1} + \ldots + k_m V_n = 0 \qquad (1)$$

where k_1, k_2, etc., are certain combinations of the coefficients of capacity and coefficients of induction involved in the basic set of equations, and V_{n+m} is the potential of a certain element at the beginning of the $(n + m)$th cycle. Each one of these equations expresses the potential of a given element in the form of a recurrent sequence, which can be evaluated by the calculus of finite differences. The general solution of (1) is:[2]

$$V_n = C_1 r_1^n + C_2 r_2^n + \ldots + C_m r_m^n$$

where $r_1, r_2, \ldots r_m$, are roots of the algebraic equation (2)

$$r^m + k_1 r^{m-1} + \ldots k_m r_m = 0$$

The roots r_1, r_2, r_3, etc., can usually be determined by inspection from the coefficients k_1, k_2, k_3, etc., and are functions only of the coefficients of capacity and induction involved in the original equations. The constants C_1, C_2, C_3, etc., depend on both the original values of the potentials of the elements of the machine, and the geometry of the machine (coefficients of capacity and induction).

In general, not all the roots are greater than unity so that as n increases a certain number of terms appearing in (2) approach zero as a limit. Some of the roots may be negative, and the corresponding terms represent oscillating sequences, giving the theory of the alternating electrostatic generator.[3]

The theory has been applied in detail to a four-element static machine

of the type exemplified by the multiplier of Belli, the machine of Varley, or the replenisher of Lord Kelvin. For this case it is found that the potential of one of the inductors is given by an equation of the form:

$$V_n = C_1 r_1^n + C_2 r_2^n$$

where, in general, r_1 is less than unity and r_2 greater than unity.

[1] J. C. Maxwell, *A Treatise on Electricity and Magnetism*, **1**, p. 110, 3d. edition, 1892.
[2] G. Boole, *A Treatise on the Calculus of Finite Differences*, Chap. 11.
[3] J. Wimshurst, *Phil. Mag.*, **31**, p. 507, 1891.

SCATTERED X-RAYS

By P. A. Ross

Stanford University

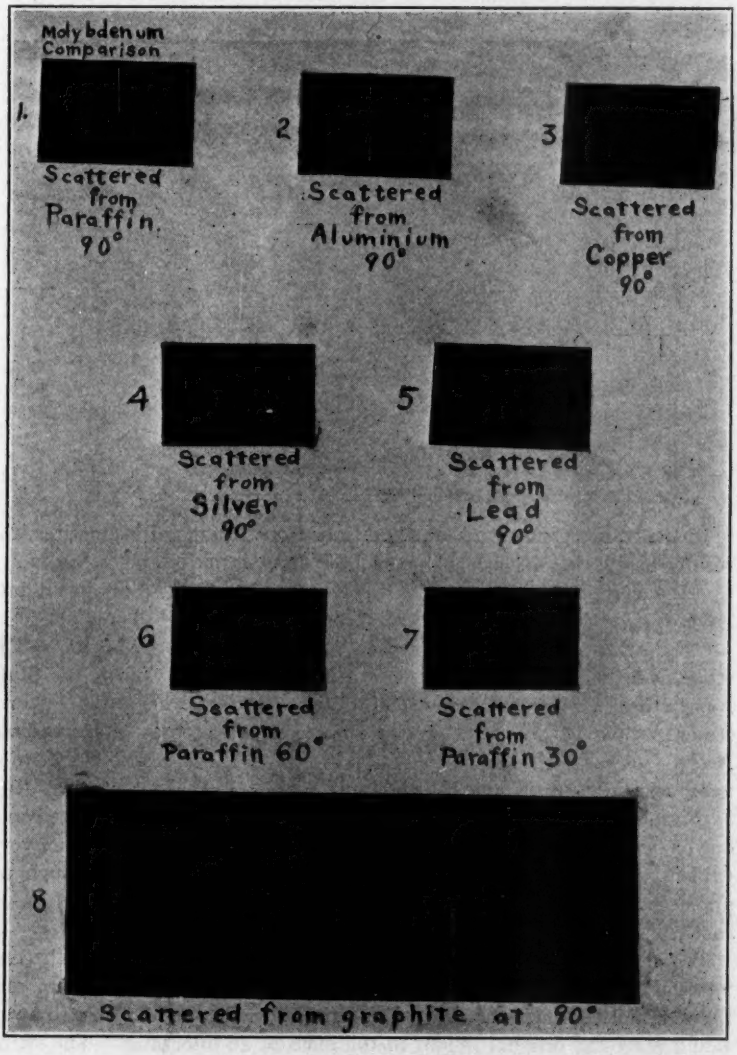
Communicated May 12, 1924

In a previous issue of these PROCEEDINGS[1] the writer published a photograph of the molybdenum K lines scattered at 90 from a paraffin block. This spectrogram showed an unshifted scattered line and a shifted line agreeing in position with that required by Compton's quantum theory of scattering.[2]

It has since been suggested[3] that the shifted line shown in the spectrogram might be explained by the tertiary radiation theory of Clark and Duane.[4] More recent and much better spectrograms make it clear that this explanation is not tenable. From the spectrograms here published which were shown at the Pasadena Meeting of the American Physical Society in September 1923,[5] it may be seen that there is a shift of the magnitude required by the Compton theory not only when the radiation is scattered by light elements but also an exactly equal shift with a heavy element such as lead. It will be seen that as we proceed toward the heavy elements the intensity of the shifted as compared with the unshifted line falls off very greatly. Spectrograms number 6 and 7 show the variation of the intensity and amount of shift with angle of scattering. The amount of shift at 30° and 60° agrees with that required by theory. That this line cannot be due to a strongly filtered tertiary peak from carbon and the shift and decrease of intensity due to greater filtering at small angles is proved by the fact that at 30° the modified line has moved past the short wave-length limit of the tertiary peak computed from the carbon K absorption limit.

In photographs 1 to 7 inclusive a water cooled molybdenum tube was used at an energy input of about 30 to 40 ma. at 30 kv. for 90 to 140 hours.

The scattering block was placed about 10 cm. from the focal spot and with its face inclined at 45° to the incident beam. The spectrograph was a fixed



crystal type with the slit-crystal and crystal-plate distances each about 30 cm. The range of wave-lengths covered by the fixed crystal was about .1 A and it was so adjusted that the lines came about the middle of this range.

Photograph 8 is molybdenum K radiation scattered from graphite. A Seeman spectrograph was used with a crystal-plate distance of 3 meters, a crystal scatterer distance of 10 cm. and an exposure of 240 hours. It will be seen that each line shows the same shift.

[1] *Proc. Nat. Acad. Sci. Washington*, **9**, No. 7, July 1923, pp. 246–8.
[2] *Physic. Rev. Ithaca*, May 1923, pp. 483–502.
[3] *Proc. Nat. Acad. Sci. Washington*, **9**, No. 12, Dec. 1923, pp. 419–424.
[4] *Ibid.*, **10**, No. 1, Jan. 1924, pp. 41–47.
[5] *Physic. Rev., Ithaca*, Nov. 1923, p. 524.

ON A STONY METEORITE FROM ANTHONY, HARPER COUNTY, KANSAS, AND A RECENTLY FOUND METEORIC IRON FROM MEJILLONES, CHILE

BY GEORGE P. MERRILL

UNITED STATES NATIONAL MUSEUM

Communicated May 8, 1924

In the course of my work on the Minor Constituents of Meteorites, the results of which have been given in the PROCEEDINGS and MEMOIRS of the Academy, several undescribed individuals from falls of unknown date have come to hand, two of which are described below:[1]—

*On a Stony Meteorite from Anthony, Harper County, Kansas.**—The stone described below was first shown the writer when visiting the State Agricultural College at Manhattan, Kansas, in November 1923, by Professor Arthur B. Sperry. To it was attached a written label reading: *Nickel-Iron meteor, found on Sec. 31, Twnshp. 23, R. 5, west 6 P. M. (6½ miles east and 1 mile south of Anthony, Harper County, Kansas) Aug. 1919 by S. T. Elliott in ploughing.* The stone was considerably oxidized and one or two prominent points were broken away, but the pittings were very evident (see Pl. 1) and its meteoric nature unmistakable. Through an arrangement with Professor Sperry the stone has been cut in halves—a cast being first made—and portions submitted to analysis.

The general appearance of the stone before cutting is shown in the two views of the plate. The dimensions were 33 cm. × 24 cm. × 16.5 cm. and the weight 19.5 kilograms. A rough estimate of the amount broken away would place the original weight of the mass at 20 kilograms. The shape is such as to suggest that it is but a fragment from a larger mass of which the face shown in figure 2 was the ruptured surface.

The stone was cut through the center in the hope—a vain one as it

proved—that the interior might have escaped oxidation and afford satisfactory material for sections and analyses. Unfortunately these hopes

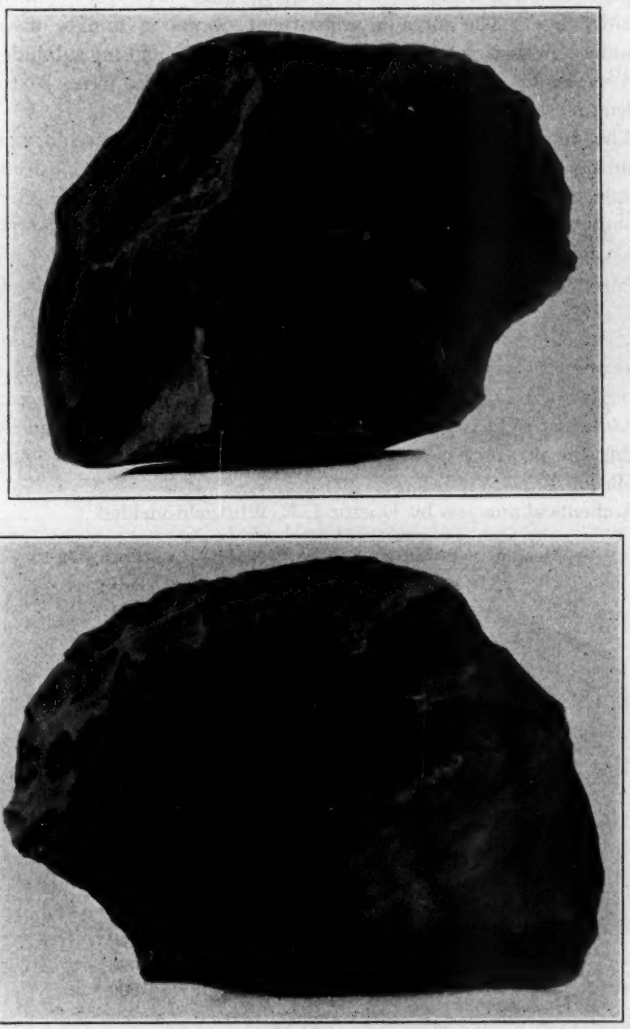


PLATE 1

The Anthony, Kansas Meteoric stone in reversed position.

were only partially realized, the oxidation staining the stone in spots throughout, though naturally somewhat unequally.

The cut surface of the stone is of a dark gray-brown color mottled with darker brown from the secondary iron oxide. The structure, notwithstanding the oxidation which stains all portions alike, is plainly chondritic to the unaided eye. The metallic constituent occurs in minute disseminated granules, in spongy-form aggregates sometimes enclosing sulphide nodules, and in slender, more or less disconnected string-like forms 20 to 30 mm. in length.

The microscopic examination, in thin sections, was somewhat disappointing, owing to the iron staining. The mineral composition is very simple, consisting, aside from the metal and sulphide, only of olivine and a rhombic pyroxene. If other minerals are present they are obscured by oxidation. The chondrules are of the ordinary stereotyped form and need no special description. Porphyritic and barred types of olivine forms are common, as are also the radiate and cryptocrystalline forms of enstatite. No feldspars nor monoclinic pyroxenes were observable. Small quantities of lawrencite made their presence known in the form of exuded drops on a freshly cut surface. Fragments immersed for but a few minutes in dilute nitric acid gave a solution reacting for phosphorus and lime, indicating the presence of the usual interstitial phosphate, now obscured by oxidation.

A chemical analysis by Doctor J. E. Whitfield yielded:

Metallic constituent 20.90%		Silicate constituent 79.10%	
SILICATE PORTION		STONE AS A WHOLE	
SiO_2	38.88	SiO_2	30.754
Al_2O_3	4.67	Al_2O_3	3.694
Fe_2O_3	1.59	Fe_2O_3	1.257
FeO	15.67	Cr_2O_3	0.561
TiO_2	0.15	TiO_2	0.118
Cr_2O_3	0.71	FeO	12.395
MnO	0.47	MnO	0.371
NiO	1.15	NiO	0.909
CoO	0.04	CoO	0.032
CaO	1.61	CaO	1.273
MgO	24.77	MgO	19.593
Na_2O	1.31	Na_2O_3	1.036
K_2O	0.16	K_2O	0.126
P_2O_5	0.36	P_2O_5	0.284
FeS	5.88	FeS	4.650
SO_3	2.65	SO_3	2.090
		Metal	20.900
	100.07		100.043

As will be noted the stone is low in silica and magnesia and above the average in content of metal, as shown in my list of selected analyses.[2] Otherwise it presents no features unusual to stones of its class. Doubtless

had it been sought a considerable amount of water would have been yielded by the secondary oxide.

The discoloration by this oxidation renders it difficult to classify exactly, but I am disposed to place it in the group of gray chondrites.

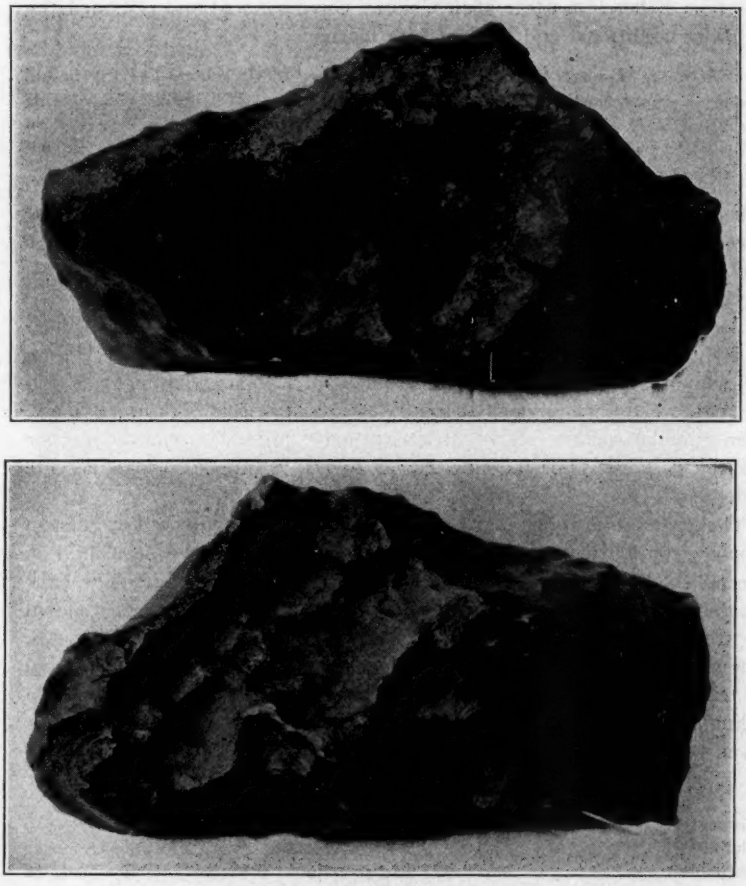


PLATE 2
The Mejillones iron in reversed positions.

*A Recently Found Meteoric Iron from Mejillones, Chile.***—The meteoric iron described below (see Pl. 2) was obtained through Ward's Natural Science Establishment. No records accompanied it other than that given on an attached adhesive slip on which was the following inscription:

Meteorite Sissidere. Caido entre el grado 23° y 24° Mayo 1905. Region Mejillones. 31 libras.

This was somewhat puzzling, since there is no record of a fall at this date. The Mejillones iron of which we have record was *found* prior to 1874 and was described by Domeyko in 1875. On request the firm mentioned therefore wrote their Chilean correspondent and obtained the following additional and confirmatory matter:

"Aerolithe Sissidere, from Mejillones:—Was found by the miners José Rivera and Manuel Ascencio Rocha in the region between the Morro (Hill) de los Guaneros de Mejillones and Caleta Herradura Grande (Big Horseshoe Harbour, literally), between latitude 23 and 24, nearer to 24. The distance from the sea is about 9 kilometers and the falling spot is a nameless sandy "pampa." Was bought from the finders in 1905."

This does not entirely clear up the matter since the mass received at the Museum is a practically complete individual, only a corner and sharp edge that could not have yielded more than 200 grams of material at most, having been broken away.

As received it was some 12 × 14 × 28 cm. in dimensions and weighed 14,530 grams, perhaps 14,700 before the portions mentioned were broken off, while the original Mejillones is reported of such size that a cart would be requisite for its carriage to post. An etched surface shows a finely, even granular surface (see Pl. 3) but without trace of Neumann lines, nor are the little areas of schreibersite arranged in any discernible definite order.

The granulation is apparently of the same nature as that in the Forsyth County iron, but is somewhat coarser, many of the granules, measured on the polished surface, being a millimeter or more in diameter. The dark area shown in the figure has a center of schreibersite granules surrounded by troilite and this in turn by a wider border of finely granular metal. The appearance is suggestive of the segregation nodules sometimes found in terrestrial rocks. An analysis by Dr. J. E. Whitfield yielded as in column I below. For purposes of comparison Domeyko's analysis[2] is given in column II.

	I	II	III
Silicon	0.008%	....	0.015
Sulphur	0.021	....	0.012
Phosphorus	0.325 Schreibersite	0.9	0.328
Nickel	5.800	3.80	5.620
Cobalt	0.460	0.10	0.430
Copper	0.010	....	0.016
Manganese	none	....	none
Carbon	none	....	0.008
Iron	93.382	95.4	93.600
	100.006%	100.2	100.029

The original Mejillones of Domeyko is classed by Brezina, Wulfing and others as a brecciated hexahedrite (Hb). I am disposed to regard the iron here described as an ataxite of the Nedagolla group (Dn). It should be noted that while differing slightly in crystalline structure, in chemical composition it is practically identical with the iron of Alpine, Texas, described by me some two years ago[4] the analysis of which is reproduced in column III above.

PLATE 3
Microstructure of Mejillones iron × eight diameters.

This finding seems to offer no relief from the usual confusion presented by Chilean findings. While the iron is not quite identical with the original Mejillones as described, it is sufficiently near it to suggest its identity. It is, however, very little oxidized, nor is the surface at all sandblasted as is so frequently the case with desert irons. It seems impossible that it

should have lain in the ground since 1874, the date of the original Mejillones. The label states plainly *fell* ("caido") in 1905. On the supposition that this is an error, is it possible that this mass is the original Mejillones described by Domeyko, from which was broken the 167 grams, now in the Paris Museum and that the large mass described was Vaca Muerta? Farrington[5] has called attention to the fact that nearly if not quite all of the so-called Mejillones iron in the various museums is really Vaca Muerta.

[1] Published by permission of the Secretary of the Smithsonian Institution.
[*] *U. S. N. M. Catalogue*, No. **725**.
[2] *Mem. Nat. Acad. Sci.*, **14**, 1916.
[**] *U. S. N. M. Cat.* No. **734**.
[3] *C. R. Paris, Acad. Sci.*, **81**, 1875, p. 597.
[4] *Proc. U. S. Nat. Mus.*, **61**, Art. 4, 1922.
[5] *Meteoric Studies* II, p. 119.

ON A METEORIC IRON FROM FOUR CORNERS, SAN JUAN COUNTY, NEW MEXICO

BY GEORGE P. MERRILL

UNITED STATES NATIONAL MUSEUM

Communicated May 16, 1924

The attention of the writer was first brought to this interesting meteorite by a letter from the late R. C. Hills, the well known mining geologist of Denver, Colorado. In this he says: "I have a meteorite weighing about fifty-five pounds* * *. It is almost a pallasite, but not quite. I have named it Four Corners, because there is no town near the location of the find, which is said to be 15 miles southeast from the common corner of Colorado, New Mexico, Arizona and Utah. I have suggested to the Trustees of the Museum [i.e., the Colorado Museum of Natural History, in Denver] that it be sent to you to cut up, analyze and describe," etc.

This proposition on the part of Mr. Hills has now been carried out with the results given below.

The meteorite as received has much the form of a water-worn boulder (see Plate 1) without deep pittings, two of the surfaces being rough as though broken during flight. The smooth "nose" was deeply incised, as with a steel chisel. The dimensions were approximately 16.5 × 26.5 × 26.5 cm. and weight 25 kilograms; that given by Mr. Hills (55 lbs.) was shown by reweighing to be correct. The name Four Corners will be retained, as sufficiently distinctive, there being no other instance of its kind within the present limits of the United States. The direction given,

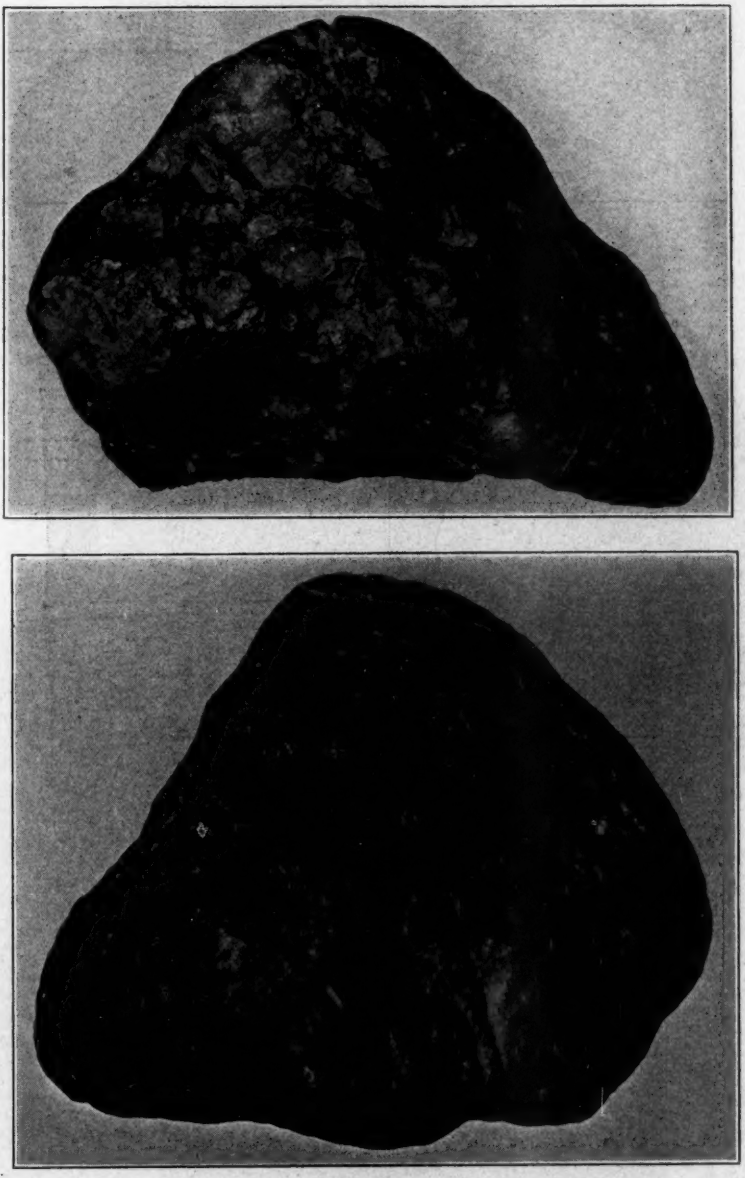


PLATE 1
The Four Corners meteorite in reversed positions.

PLATE 2
Polished slice of Four Corners meteorite. About four-fifths natural size.

Polished slice of Four Corners meteorite. About four-fifths natural size.

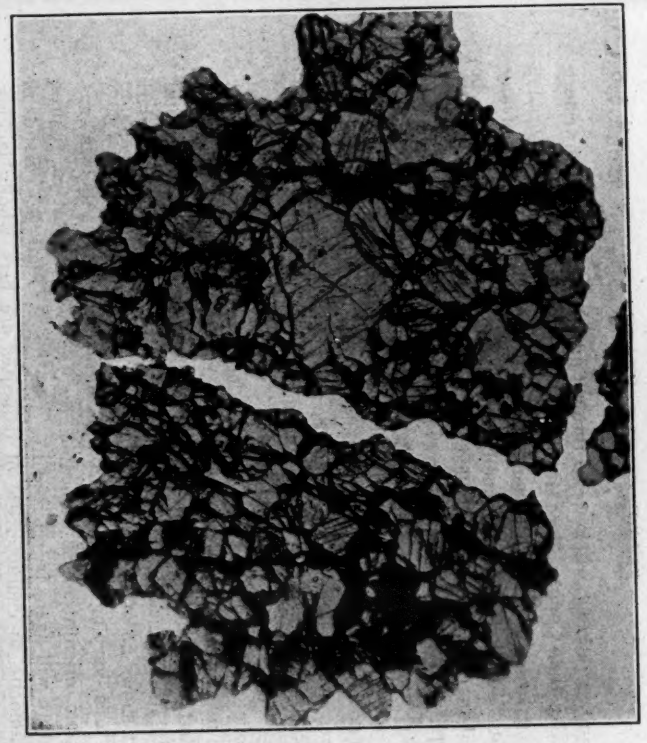


PLATE 3

Fig. 2. Slightly magnified etched slice of the same. The black areas are the silicate areas; the light gray, kamacite and plessite; the white, taenite. Photomicrograph by Lewis E. Jewell.

Fig. 1. Chondroidal aggregate of pyroxenes in silicate portion of the Four Corners meteorite.

i.e., 15 miles southeast, will however throw it into the extreme northwestern part of San Juan County, New Mexico.

The structure as shown in Plate 2 is quite different from that of any meteorite which I have personally examined. The metal it will be observed predominates, but is filled with dark irregular large and small enclosures up to 15 mm. in diameter which on examination prove to be very fine grained crystalline granular aggregates of pyroxenes with a little olivine, often considerable amounts of iron phosphide and sulphide, and a few feldspathic granules and particles of calcium phosphate. These enclosures are distributed throughout the mass in form of mere sand grains or angular masses up to the dimensions given. In thin section under the microscope they show occasional clustered aggregates suggestive of chondrules, one of which is shown in Figure 1, Plate 3. The pyroxenic constituents are nearly colorless enstatite and bright green diopside. It is to be noted that these enclosures are always angular and plainly fragmental. The metal itself etched with either bromine or nitric acid quickly turns dark gray but shows no other signs of oxidation. It is noteworthy that each metallic area, varying from 10 to 20 mm. in diameter shows its own crystallographic orientation as indicated by the Widmanstätten figures. This feature will again be referred to. (See fig. 2, Plate 3.) Bands of wickel-kamacite so characteristic of pallasites are here wholly lacking. The plessite areas are usually small, the taenite distinct, though having little relief on the etched surface. Schreibersite in small granular aggregates usually associated with the silicate enclosures is not uncommon. Troilite in small particles associated with and distributed throughout the silicates is abundant, but there are none of the rounded nodular forms so common in meteoric irons. Small particles of metal, it should be stated, occur irregularly throughout the silicate fragments.

A characteristic sample of the meteorite, (one in which the silicate portions were so distributed as to be representative of the meteorite as a whole) was submitted to Dr. J. E. Whitfield with the following results:

	METALLIC PORTION PERCENT
Silicon	0.152
Sulphur	0.021
Phosphorus	0.147
Copper	0.035
Nickel	9.575
Cobalt	0.590
Carbon	0.201
Iron	89.300
	100.021

This, it will be observed, agrees well with the analyses of the fine octahedrite of Perryville, Missouri[1] or the metal from the Krasnojarsk pallasite as given by Whitfield.[2] The silicate portion yielded 47.16% soluble in dilute hydrochloric acid and 52.84% insoluble. The soluble portion contained the olivine, doubtless a portion of the feldspar, the calcium phosphate and the iron sulphide. An accident prevented its complete

analysis. The insoluble portion, a mixture of the two pyroxenes and feldspar, yielded as follows:

	PER CENT
Silica (SiO_2).....	62.57
Alumina (Al_2O_3).....	9.37
Lime (CaO).....	3.54
Magnesia (MgO).....	19.77
Ferrous iron (FeO).....	1.27
Carbon (graphitic).....	3.46
	99.98

The specific gravity of a 425-gram slice selected as typical of the mass was 6.62. Of a small piece of the metal, free from silicate enclosures, 7.88.

The whole aspect of this meteorite is unusual and difficult to explain. It is obvious that the silicates could not have crystallized out of a highly ferriferous magma in their present form. Their ragged and angular shapes are wholly against this, nor can they be considered merely as fragments caught up in a molten metallic magma, as has been suggested, since they show no evidences whatever of corrosion. They might perhaps be accounted for by assuming them to be products of disintegration from a previously existing finely granular siliceous stone, the particles from which became admixed with some ferriferous compound reducible at temperatures considerably below the normal melting point of iron, as long ago suggested by Meunier. The fact that the individual plates of the iron, as previously noted and as brought out by etching are of limited extent instead of being continuous over considerable areas, as in ordinary octahedral iron, suggests however a one time coarsely granular mass of metallic and silicate fragments, since compressed. Just how much reliance can be placed upon such a suggestion is perhaps doubtful, since any crystalline aggregate, as of calcite or feldspar will show a like diversity in crystallographic orientation.

The closest analogue of this iron would appear to be that of Copiapo (Dheesa) Chile described by Haidinger,[3] Daubree[4] and Meunier[5] but of which unfortunately our Museum has no sample for comparison. An analysis of the metallic portion of the Copiapo fall by Dr. E. Dittler, as given by Berwerth[6] yielded: Fe 87.40, Ni 11.97, Co 0.56, schreibersite 0.07. The silicate analysis given by Meunier points unmistakably to olivine and pyroxene as the chief constituents. The similarity of the two is also shown by Meunier's Figure 39 in the work cited.[7]

The Four Corners meteorite cannot be made to conform readily with any existing and generally accepted scheme of classification. Mr. Hills described it as "almost a pallasite," but it is not like any known member of this group. From its nearest approximate, the pallasites of the Rokicky group, it differs in that in the latter the siliceous portion consists wholly of large olivine blebs in a more or less fragmental condition, while in the Four Corners the inclusions are rock fragments of a complex nature. The meteorite is really a breccia composed of fragments of a fine grained, py-

roxenic rock with an excess of cementing material in the form of coarse granular nickel-iron. In this respect it differs from the Kodai Kanal iron described by Berwerth, in which the silicate fragments are crystalline secretions from a ferriferous magma. Viewed in this light it would then seem best to class it with the Copiapo (Dheesa) fall as a granular octahedral iron with silicate enclosures.

[1] *Proc. U. S. Nat. Museum*, **43**, 1912, pp. 595–597.

[2] *Handbook Meteorite Collections, U. S. N. M.*, p. 93.

[3] *Sitz. Akad. Wiss. Wien.*, **49**, 1864, p. 490.

[4] *C. R. Acad. Sci., Paris*, **66**, 1868, p. 571.

[5] *Meteorites*, (Fremy's Encyclopedie Chimique), 1884, p. 152.

[6] *Tschermak's Min. Pet. Mittheil*, **34**, 1917, p. 272.

[7] There being no available slices for comparison a portion of the Four Corners meteorite, shown in pl. 2 was sent to Dr. Meunier, from whom was received a reply of which the following is an abstract:

> "La photographie que vous m'avex envoyeé de votre météorite metamorphique que vous comparez si vraisembleblement a la pierre de Deesa, est remarquable par sa netteté et par son eloquence; on y voit que l'alliage metallique a fait eruption an travers d'un banc de roche grisatre ordinari et la noiree jusqu' au coeur de la substance, le metal s'est consolidé tres tranquellement ce qui lui a permis de presider a la cristallization de aiguilles et de lamelles a composition chemique parfaitement definie. Votre echantillon est des plus preceux pour prouver de communnaté de gisementide different types de meteorites dans une masse apporté parun seul bolide conformenent a l'opinion que J'ai developpeé."
>
> Meunier, April 21, 1924.

THE CONSTITUTION OF COLUMBIA YELLOW (CHLORAMINE YELLOW)

BY MARSTON TAYLOR BOGERT AND FRANK H. BERGEIM

ORGANIC LABORATORIES, COLUMBIA UNIVERSITY

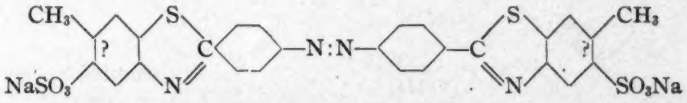
Read before the Academy, April 29, 1924

Columbia Yellow, or Chloramine Yellow, Schultz No. 617, rejoices in at least a dozen different names and is marketed in various brands. All are manufactured by the action of sodium hypochlorite upon the sodium sulfonate of dehydrothio-*p*-toluidine (NN type), of primuline (B type), or of mixtures of the two (FF type), the shades varying accordingly and the different brands betokening this. Among the direct cotton colors, it is conspicuous for its excellent fastness to light, chlorine and alkali.

The fact that the dye was produced by alkaline oxidation of a primary aromatic amine, and that the product no longer contained a diazotizable amino group, led to the belief that it was probably of azo or azoxy type. But certain peculiarities of behavior, notably its resistance to either ox-

idizing or reducing agents, and its failure to regenerate dehydrothio-*p*-toluidine sulfo acid by such reduction, early cast doubt upon such a structure, and stilbene or quinone formulas were among the other possibilities suggested. In the absence of experimental proof, some writers have assumed the azo structure, others (like Schultz) have withheld the assignment of any formula until such evidence was supplied.

We believe that our experimental data furnish adequate proof that the dye is really the azo derivative and that it probably possesses this constitution:



(1)

although the position of the sulfo groups has not been determined definitely as yet.

The attack upon the problem was developed along the following lines:

1. Purification and analysis of a high-grade sample of the commercial dye, involving also a determination of its molecular weight by chemical methods.

2. The synthesis of the dye by reduction of 2-*p*-nitrophenyl-6-methylbenzothiazole to the corresponding azo compound and sulfonation of the latter.

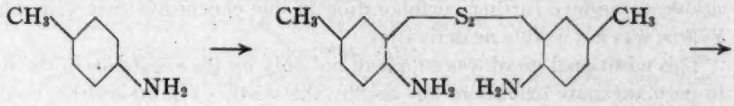
3. The synthesis, by a similar method, of an analogous dye differing from the above only in lacking its methyl groups, to prove that stilbene formation played no part in the reaction.

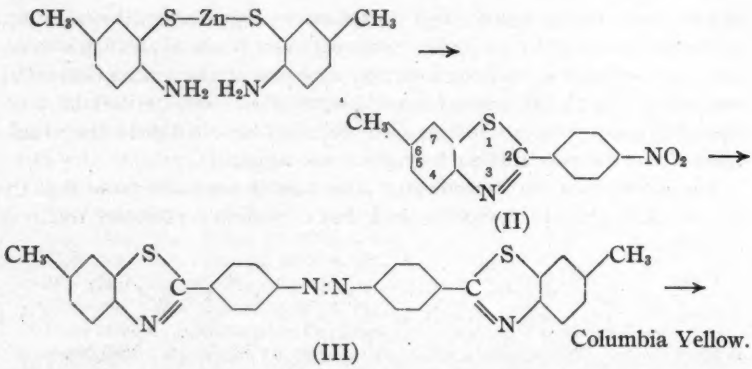
4. The preparation from dehydrothio-*p*-toluidine sulfo acid of the corresponding hydroxy sulfo acid, alkaline oxidation of which gave no dye whatever, proving that the amino group was essential and that there was no quinone formation.

1. Purification and Analysis of the Commercial Dye.—This was undertaken by two different methods—(*a*) through the free sulfo acid, and (*b*) through its cerium salt.

Although complete purification was not accomplished by either method, largely because of the colloidal nature of these substances, products were obtained whose percentage composition approached closely to that represented by Formula I.

2. Synthesis of Columbia Yellow by Reduction of the Nitro Compound.—The starting point for the synthesis was *p*-toluidine, and the various steps were these:





From a *p*-toluidine sulfur melt, the *p*-toluidine disulfide was extracted by dilute (10%) sulfuric acid, and reduced in glacial acetic acid solution with zinc dust. *p*-Nitrobenzoyl chloride converted this into 2-*p*-nitrophenyl-6-methyl-benzothiazole (II), which was reduced to the azo compound (III) in the customary manner by digesting its alcoholic solution with zinc dust and caustic alkali. Sulfonation of the azo compound under conditions identical with those employed for the sulfonation of dehydrothio-*p*-toluidine itself, yielded a yellow dye indistinguishable from Columbia yellow.

What was apparently the same product (Columbia Yellow) was obtained by reducing this same *p*-nitrophenyl-6-methyl-benzothiazole (II) to the corresponding amine (dehydrothio-*p*-toluidine), sulfonating this and oxidizing the sodium sulfonate with hypochlorite in the usual way.

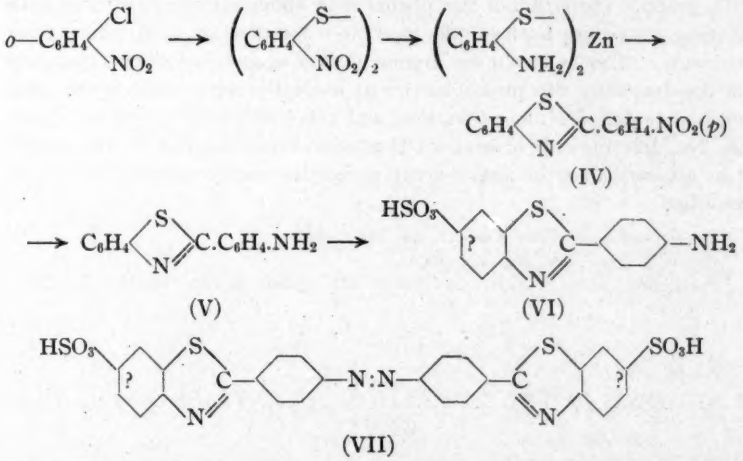
By a careful comparison of the physical, chemical and tinctorial properties of these two products we were unable to distinguish between them and, therefore, are of the opinion that they were identical.

Since the work of Bogert and Snell[1] has shown that the sulfo group in dehydrothio-*p*-toluidine monosulfo acid is probably at Position 5, it seems likely that the sulfo groups in Columbia Yellow are similarly located, and we have so represented them in Formula I, but positive experimental proof of this still is lacking.

3. Synthesis of the First Member of the Columbia Yellow Series.—Since the oxidation of aromatic methyl groups to stilbene unions has been observed frequently,[2] and the simpler stilbene dyes, of nitroso, azoxy, or azo type, such as Sun Yellow, Chrysophenine, Mikado Yellow, etc., are likewise direct yellow dyes of somewhat similar properties, it was desirable to adduce further corroboration of our conclusion that Columbia Yellow was not a stilbene derivative.

This additional proof was supplied, not only by the resistance of the dye to permanganate oxidation, but also by the synthesis of an entirely analo-

gous dye (VII) from 2-*p*-aminophenylbenzothiazole sodium sulfonate (VI), by oxidation with sodium hypochlorite in exactly the same way in which we prepared Columbia Yellow itself from dehydrothio-*p*-toluidine sodium sulfonate. The various steps in this synthesis were the following:



(IV) (V) (VI)

(VII)

This dye (VII) resembled Columbia Yellow in all its physical, chemical and tinctorial properties, with the exception that its dyeings upon cotton were of a much paler yellow shade with the same proportion of dye, namely 2% the weight of the fabric. Its affinity for the cotton fiber was fully as great as that of Columbia Yellow. It follows from this, then, that the affinity for cotton fiber resides in the simple azo complex represented by Formula VII, and that the methyl groups merely deepen the shade. This agrees with the observation of the original patentee[3] that redder shades were obtained with the corresponding dyes from dehydrothio-*m*-xylidine and dehydrothio-pseudocumidine.

4. *The Preparation from Dehydrothio-p-toluidine Sulfo Acid of the Corresponding Hydroxy Sulfo Acid,* $HSO_3(CH_3)C_6H_2$ CC_6H_4OH.—

Other reactions which aromatic primary amines may undergo when subjected to the action of alkaline hypochlorites lead to the formation of quinones, quinoneimines, chlorimines or chloramines.

The great resistance of Columbia Yellow to acids or alkalies, oxidizing or reducing agents, is a cogent argument against the assumption of any such structure for it. As the purified dye contains no chlorine whatever, it cannot be of chloramine or chlorimine type.

As further evidence that the dye is neither a simple quinone, nor owes

its color to quinoid oxygen, dehydrothio-*p*-toluidine sulfo acid was converted through its diazo compound, into the corresponding 2-*p*-hydroxyphenyl-6-methyl-benzothiazole sulfo acid, which differs from the original dehydrothio-*p*-toluidine sulfo acid only in carrying an OH in place of the NH_2 group. Oxidation of this phenol with alkaline hypochlorite, or with alkaline potassium ferricyanide, gave no color reaction or dye formation whatever. This is one more argument also against a stilbene structure for the dye, since this phenol carries its methyl group in exactly the same position as dehydrothio-*p*-toluidine, and hence should have yielded a similar dye, differing only in having OH as auxochrome instead of NH_2, unless it be assumed that the amino group is simultaneously oxidized to the azo condition.

[1] Bogert and Snell, *Color Trade J.*, **14**, 151 (1924).
[2] Green, *J. Chem. Soc.*, **85**, 1424 (1904).
[3] Farbenfabr. vorm. F. Bayer, *Ger. Pat.* 65,402; *Friedl.*, **2**, 752; *Winther*, **2**, 1222.

A SYNOPSIS OF THE IONIZATION POTENTIALS OF THE ELEMENTS

BY CECILIA H. PAYNE

HARVARD COLLEGE OBSERVATORY, CAMBRIDGE, MASS.

Communicated June 3, 1924

The rapid advances which are taking place in the analysis of spectra at the present time have resulted in the accumulation of much new information on ionization potentials. In the present paper it is proposed to collect the results from physical, spectroscopic, and astrophysical sources which bear on this subject. The aspect from which the material will be summarized is not new, having been considered by Russell,[1] by Saunders,[2] and probably elsewhere. The tabulation and diagram contain, however, some more recently published data, and the inclusion of the material for second and third ionizations is new.

Table I contains a summary of the best values at present assigned to the ionization potentials of the various elements. Successive columns give the atomic number, the chemical symbol of the element, the physical, spectroscopic, or astrophysical ionization potential, and the authority for the value quoted.

The physically and spectroscopically determined ionization potentials require no comment, except to note that the spectroscopic values are of a higher order of accuracy, and also that the identification of the corresponding state of the atom is less uncertain.

TABLE I

SYNOPSIS OF IONIZATION POTENTIALS

ATOMIC NUMBER	ELEMENT	IONIZATION POTENTIAL PHYSICAL	IONIZATION POTENTIAL SPECTROSCOPIC	IONIZATION POTENTIAL ASTROPHYSICAL	REFERENCE
1	H	14.4	———	———	Horton and Davies, *Proc. Roy. Soc.*, **97A,** 23, 1920
		13.3	———	———	Mohler and Foote, *Journ. Op. Soc. Am.*, **4,** 49, 1920
		———	13.54	———	Fowler, *Report*[3]
2	He	———	24.47	———	Lyman, *Phys. Rev.*, **21,** 202, 1923
		25.4	———	———	Horton and Davies, *Proc. Roy. Soc.*, **95A,** 408, 1919; *Phil. Mag.*, **39,** 592, 1920
	He^+	———	54.18	———	Fowler, *Report*
		54.3	———	———	Horton and Davies, *Proc. Roy. Soc.*, **95A,** 408, 1919; *Phil. Mag.*, **39,** 592, 1920
3	Li	———	5.37	———	Fowler, *Report*
	Li^+	40	———	———	Mohler, *Science*, **58,** 468, 1923
6	C^+	———	24.3	———	Fowler, *Proc. Roy. Soc.*, **105A,** 299, 1924
	C^{++}	———	———	45	Payne, *Harv. Obs. Circ.* 256, 1924
7	N	17.75	———	———	Brandt, *Zeit. für Phys.*, **8,** 32, 1921
	N^+	———	———	24	Payne, *Harv. Obs. Circ.*, 256, 1924
	N^+?	25.41	———	———	Brandt, *Zeit. für. Phys.*, **8,** 32, 1921
	N^{++}	———	———	>45	Payne, *Harv. Obs. Circ.*, 256, 1924
8	O	———	13.56	———	Fowler, *Report;* Hopfield, *Nature*, **112,** 437, 1923; *Ap. J.*, **59,** 114, 1924
		15.5	———	———	Mohler and Foote, *Journ. Op. Soc. Am.*, **4,** 49, 1920
	O^+	———	———	32	Payne, *Harv. Obs. Circ.*, 256, 1924
10	Ne	16.7	———	———	Horton and Davies, *Proc. Roy. Soc.*, **98A,** 121, 1920
11	Na	———	5.12	———	Fowler, *Report*
		5.13	———	———	Tate and Foote, *Phil. Mag.*, **36,** 64, 1918
	Na^+	30 to 35	———	———	Foote, Meggers and Mohler, *Ap. J.*, **55,** 145, 1922
12	Mg	———	7.61	———	Fowler, *Report*
		7.75	———	———	Foote and Mohler, *Phil. Mag.*, **37,** 33, 1919

TABLE I (*Continued*)

ATOMIC NUMBER	ELEMENT	IONIZATION POTENTIAL PHYSICAL	IONIZATION POTENTIAL SPECTROSCOPIC	IONIZATION POTENTIAL ASTROPHYSICAL	REFERENCE
		8.0	———	———	Mohler, Foote and Meggers, *Bur. Stan.*, 734, 1920
	Mg^+	———	14.97	———	Fowler, *Report*
13	Al	———	5.96	———	Fowler, *Report*
	Al^+	———	18.18	———	Paschen, *Ann. d. Phys.*, **71,** 151 and 537, 1923
	Al^{++}	———	28.32	———	Paschen, *Ann. d. Phys.*, **71,** 151 and 537, 1923
14	Si	———	10.6	———	Fowler, *Bakerian Lecture,* 1924
	Si^+	———	16.27	———	Fowler, *Bakerian Lecture,* 1924
	Si^{++}	———	31.66	———	Fowler, *Bakerian Lecture,* 1924
	Si^{+++}	———	44.95	———	Fowler, *Proc. Roy. Soc.*, **103A,** 413, 1923
15	P	13.3	———	———	Mohler and Foote, *Phys. Rev.*, **15,** 321, 1920
16	S	———	10.31	———	Hopfield, *Nature,* **114,** 437, 1923
		12.2	———	———	Mohler and Foote, *Phys. Rev.*, **15,** 321, 1920
	S^+	———	———	20	Payne, *Harv. Obs. Circ.*, 256, 1924
	S^{++}	———	———	32	Payne, *Harv. Obs. Circ.*, 256, 1924
17	Cl	8.2	———	———	Hughes and Dixon, *Phys. Rev.*, **10,** 495, 1917.
18	A	15.1	———	———	Horton and Davies, *Proc. Roy. Soc.*, **102A,** 131, 1922
	A^+	33	———	———	Shaver, *Trans. Roy. Soc. Can.*, **16,** 135, 1922
		34	———	———	Horton and Davies, *Proc. Roy. Soc.*, **102A,** 131, 1922
19	K	———	4.32	———	Fowler, *Report*
		4.1	———	———	Tate and Foote, *Phil. Mag.*, **36,** 64, 1918
	K^+	20 to 23	———	———	Foote, Meggers and Mohler, *Ap. J.*, **55,** 145, 1922
20	Ca	———	6.09	———	Fowler, *Report*
	Ca^+	———	11.82	———	Fowler, *Report*
21	Sc	———	———	6 to 9	Russell, *Ap. J.*, **55,** 119, 1922
22	Ti	———	5.61	———	Kiess and Kiess, *Journ. Op. Soc. Am.*, **8,** 609, 1924
23	V	———	———	6 to 9	Russell, *Ap. J.*, **55,** 119, 1922

24	Cr	———	6.7	———	Catalan, *Comptes Rendus*, **176**, 1063, 1923
25	Mn	———	7.41	———	Catalan, *Phil. Trans.*, **223A**, 1922
26	Fe	———	5.9	———	Sommerfeld, *Physica*, **4**, 115, 1924
27	Co	———	———	6 to 9	Russell, *Ap. J.*, **55**, 119, 1922
28	Ni	———	———	6 to 9	Russell, *Ap. J.*, **55**, 119, 1922
29	Cu	———	7.69	———	Fowler, *Report*
30	Zn	———	9.35	———	Fowler, *Report*
31	Ga	———	5.97	———	Fowler, *Report*
33	As	11.5	———	———	Ruark, Mohler, Foote and Chenault, *Nature*, **112**, 831, 1923
34	Se	12 to 13	———	———	Foote and Mohler, *The Origin of Spectra*, **67**, 1922
		11.7	———	———	Udden, *Phys. Rev.*, **18**, 385, 1921
35	Br	10.0	———	———	Hughes and Dixon, *Phys. Rev.*, **10**, 495, 1917
36	Kr	14.5	———	———	Sponer, *Zeit. für Phys.*, **18**, 249, 1923
37	Rb	———	4.16	———	Fowler, *Report*
		4.1	———	———	Foote, Rognley and Mohler, *Phys. Rev.*, **13**, 61, 1919
38	Sr	———	5.67	———	Fowler, *Report*
	Sr^+	———	10.98	———	Fowler, *Report*
42	Mo	———	7.1	———	Catalan, *Comptes Rendus*, **176**, 1063, 1923
		———	7.35	———	Kiess, *Bur. Stan. Sci. Papers*, **474**, 113, 1923
49	In	———	5.75	———	McLennan, *Pres. Address to Sect. A, Brit. Assoc.*, 1923
53	I	10.1	———	———	Foote and Mohler, *The Origin of Spectra*, 67, 1922
		8.0	———	———	Smyth and Compton, *Phys. Rev.*, **16**, 502, 1920
56	Ba	———	5.19	———	Fowler, *Report*
	Ba^+	———	9.96	———	Fowler, *Report*
80	Hg	———	10.4	———	Eldridge, *Phys. Rev.*, **20**, 456, 1922
81	Tl	———	6.04	———	Mohler and Ruark, *Journ. Op. Soc. Am.*, **7**, 819, 1923
82	Pb	———	7.38	———	Grotrian, *Zeit. für Phys.*, **18**, 169, 1923

TABLE I (*Concluded*)

ATOMIC NUMBER	ELEMENT	IONIZATION POTENTIAL PHYSICAL	SPECTROSCOPIC	ASTROPHYSICAL	REFERENCE
			7.93		Foote and Mohler, *The Origin of Spectra*, 65, 1922
83	Bi	8.0			Ruark, Mohler, Foote and Chenault, *Nature*, **112**, 831, 1923
	Bi^+	14			Ruark, Mohler, Foote and Chenault, *Nature*, **112**, 831, 1923

The possibility of making astrophysical estimates of ionization potential is a direct result of the Saha theory of ionization in stellar atmospheres.[4] It appears, from the success with which this theory has accounted for the chief features of stellar spectra, that Saha's basic assumption that thermal ionization can be treated as a type of chemical dissociation is fully justified. The fundamental formula, which is essentially the Law of Mass Action, regards the ionization potential as the latent heat of evaporation of the electron from the atom or molecule.[5] Saha himself applied his theory to the estimation of ionization potentials, and subsequently Russell[6,7] has discussed the subject more fully.

The subject of thermal ionization in stellar atmospheres has been treated by Fowler and Milne,[8] using the methods of statistical mechanics. This form of the theory has an advantage, compared with Saha's, in that it involves the temperature at which a given absorption line will be at maximum intensity, rather than the temperature of disappearance.

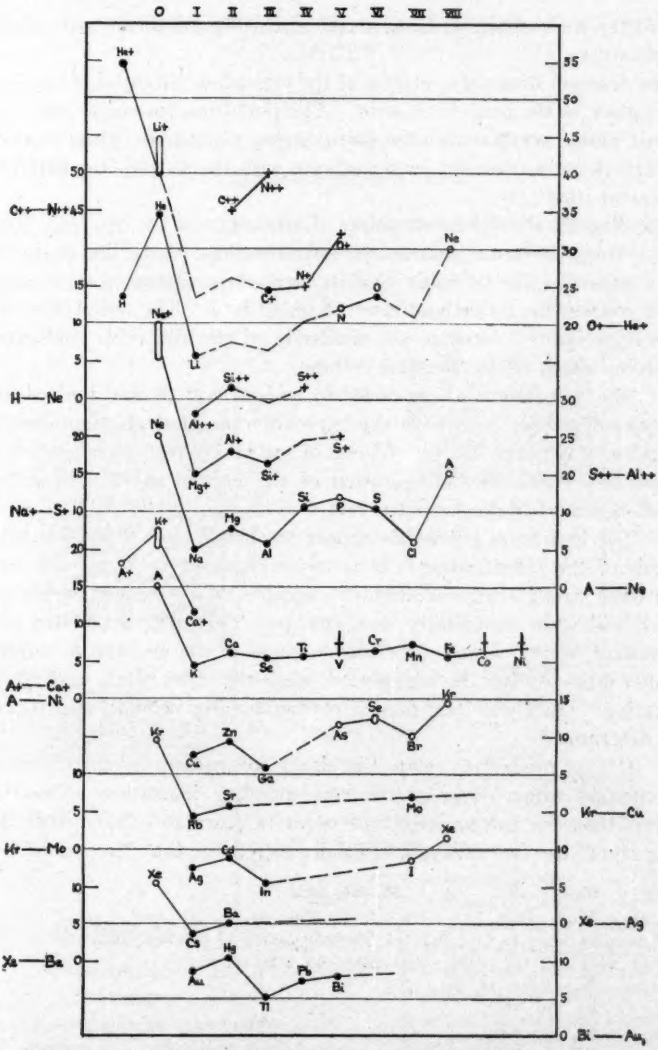
A determination of the maxima of the lines in stellar spectra for a number of elements has recently been made by the writer.[9] A stellar temperature scale for the reversing layer of the hotter stars, derived from the observations of lines corresponding to known critical potentials, is given in Table II. Its values are somewhat higher than those derived by other methods.

TABLE II

SCALE OF STELLAR TEMPERATURES

SPECTRAL CLASS	TEMPERATURE	SPECTRAL CLASS	TEMPERATURE
Od	28,000?	B3	16,000
Oe	26,000	B5	15,000
Oe5	23,000	B8	13,500
B0	20,000	B9	12,600
B1	18,500	A0	11,000
B2	17,500		

From this temperature scale and the critical potentials used in its derivation, it is possible, on reasonable assumptions,[10] to estimate the ionization potential of any element, if its spectrum lines are known to have a maximum at a given stellar type. The astrophysical estimates made by



Relation between ionization potential and atomic number. Abscissae are columns of the periodic table; ordinates are ionization potentials, all drawn to the same scale. The zeros for the different parts of the diagram are indicated on alternate left and right margins. Spectroscopic ionization potentials are shown by filled circles, open circles give physical determinations, and crosses represent astrophysical estimates. Conjectural portions of the curves are shown by broken lines. The points for Fe, P, As, and the halogens are to be considered somewhat uncertain.

the writer were obtained from a curve relating ionization potential and temperature.

The diagram shows the relation of the ionization potential of an element to its place in the periodic system. The potentials for singly and doubly ionized atoms are inserted, the points being shifted one place to the left for each electron removed, in accordance with the Kossel-Sommerfeld displacement rule.

The diagram shows several points of interest:

1. From any one column to the next the slope of the line is similar in every period. This is most clearly marked in Columns 0, I, and II, which contain the fullest and most accurate data. The uniformity of this slope is probably related to the similarity of electron orbit configuration for atoms which fall in the same column.

2. The few points which relate to ionized and doubly ionized atoms correspond satisfactorily with the curves for the neutral atoms (with the exception of C^{++} and N^{++}). This is of special interest in connection with the supposed electron configuration of the ionized atom, and with the Kossel-Sommerfeld displacement rule.

3. The ionization potentials appear to change only slowly in the long periods of the classification. It is to be expected that the rare earths, with their strong chemical similarity apparently dependent on the outer orbits, will show a similarly slow change. This may be related to the theoretical work[11] which recognizes changes in the electron arrangement of inner orbits during the long period, while the outer orbits undergo little alteration. Only one long period, containing iron, cobalt, and nickel, is well determined.

4. It is of interest to relate the zigzag form taken by the curves with the changes which occur at the corresponding ionization. The curves suggest that the valence electrons occur in pairs and that, other things being equal, the first of a pair is harder to remove than the second.

[1] *Ap. J.*, **55**, 119, 1922; *Ap. J.*, **55**, 354, 1922.
[2] *Science*, **59**, 47, 1924.
[3] Report on Series in Line Spectra, *Physical Society of London*, 1922.
[4] *Phil. Mag.*, **40**, 472, 1920; *Phil. Mag.*, **40**, 809, 1920.
[5] Milne, *Observatory*, **44**, 261, 1921.
[6] *Ap. J.*, **55**, 119, 1922.
[7] *Ap. J.*, **55**, 354, 1922.
[8] *M. N. R. A. S.*, **83**, 403, 1923.
[9] *Harv. Obs. Circ.* 252, and 256, 1924.
[10] It is assumed that the partial electron pressure is constant at about 10^{-4} atm. (*Harv. Obs. Circ.*, 252).
[11] Ladenburg, *Naturwiss.*, **13**, 248, 1924.

THE INHERITANCE OF A RETINAL ABNORMALITY IN WHITE MICE*

BY CLYDE E. KEELER

ZOÖLOGICAL LABORATORY, HARVARD UNIVERSITY

Communicated June 3, 1924

Although various accounts have appeared in the literature regarding the hereditary nature of ophthalmic anomalies found or produced experimentally in rodents, they have dealt chiefly with abnormalities of pigmentation (Cuenot, '02; Castle and Little, '09), cornea, lens, and lid (Stockard and Papanicolaou, '16; Guyer and Smith, '20; Bagg and Little, '24). Furthermore, these are usually macroscopic in nature and in many cases can be recognized with the naked eye. The abnormality to

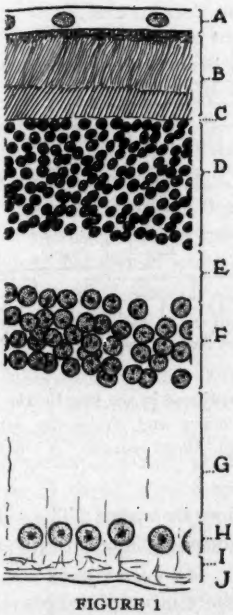


FIGURE 1

A camera lucida drawing of a portion of a retina from normal animal No. 9 × 435 (Fig. 3).

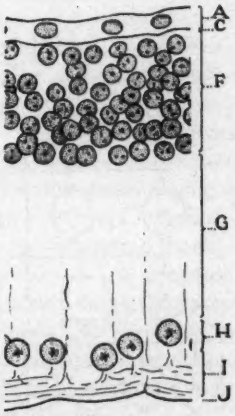


FIGURE 2

A camera lucida drawing of a portion of a retina from abnormal animal No. 3 × 435 (Fig. 3).

A = Epithelial layer.
B = Visual cell layer.
C = External limiting membrane.
D = External nuclear layer.
E = External molecular layer.
F = Internal nuclear layer.
G = Internal molecular layer.
H = Ganglionic layer.
I = Optic fibers.
J = Internal limiting membrane.

be described in this paper, as far as it has been studied, is strictly retinal in extent and can only be revealed by microscopic examination.

In October 1923 a male albino mouse (fig. 3, No. 4) was killed for the purpose of studying the retina. The eyes were excised and fixed. Microscopic sections of these eyes showed the total absence of the visual cells (rods), the external nuclear layer, and the external molecular layers (fig. 2). Just beneath the external limiting membrane, which was hard to demonstrate, there occurred a band of nuclei (fig. 2, F). This was taken to be the internal nuclear layer (cf. F, fig. 1). The cells of this layer appeared normal in size, shape, and in the characteristic clumping of the chromatin. The width corresponds closely to the normal. The internal

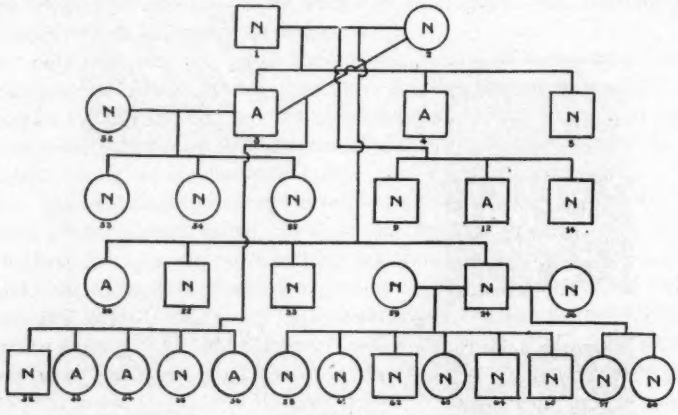


FIGURE 3

A pedigree chart representing the animals mentioned in the text by the numbers which appear under them. Squares are males and circles are females. Individuals marked "N" have a normal retina, those marked "A" have an abnormal retina.

molecular layer resembles the normal, but may be wider. The ganglionic cells and the optic nerve fibres appeared normal. The internal limiting membrane was present in all cases.

The eyes of a litter-brother (No. 5) and those of another (No. 12) from a litter born of the same parents as individual Nos. 4 and 5, were subjected to identical treatment, and the sections were mounted on the same slides. The retina of No. 5 was found to be entirely normal, whereas No. 12 showed the same defect as did No. 4. Failure to find the visual cells in these two cases was obviously not to be ascribed to their loss through faulty technique.

It was decided to breed this strain of mice in order that the defect might be studied from the standpoint of its inheritance. In order to make

known matings, it was necessary to distinguish between normal and abnormal animals. Since no external evidence of the abnormality was observed, several simple behavior tests were devised for the purpose of distinguishing between normal and abnormal animals. These gave undependable results as the animals are guided so remarkably by their vibrissae. In consequence of this difficulty, definite knowledge concerning the retinal condition was obtained by excising one eye and studying it histologically. The enucleation was done under anesthesia by tying off the eye with a thread, and then cutting the orbital connection. All the animals represented in the pedigree chart, with the exception of Nos. 4, 5, 12, 14 and 20, which had previously been killed for the examination of the eyes, were operated upon successfully.

To make a survey of the stock from which Nos. 1 and 2 originated, (fig. 3)—they being litter-sibs—animals were chosen at random from this strain. The right eye was removed and sectioned in the case of five males and ten females. The retina of one male and of eight females was found to be abnormal. Both eyes of six female mice of an unrelated strain were sectioned and found to be normal. To this strain belong Nos. 52, 56 and 59 (fig. 3). In all cases where both eyes were examined (eight cases from the original stock and six from the unrelated stock) the abnormality, when present, occurred in both eyes. The variation in the degree of the abnormality was slight and confined, in all the cases thus far observed, to the retinal layers already described. No autopsies have been made to determine whether any associated abnormalities might be present as described by Bagg '24 to be associated with eye abnormalities occurring in descendants of mice subjected to X-ray irradiation.

The inheritance of this defect has not been investigated far enough to give definite information, although a study of the pedigree chart (fig. 3) offers suggestive data. Nos. 1 and 2, brother and sister, having normal eyes but perhaps carriers of the defect, were mated three times. In their first litter of three, Nos. 3 and 4 were abnormal and No. 5 was normal. In their second litter of three, No. 12 was abnormal and Nos. 9 and 14 were normal. In their third litter of four, No. 20 was abnormal and Nos. 22, 23 and 24 were normal. Of the ten offspring, then, of Nos. 1 and 2, four were abnormal and six were normal. The abnormal No. 3 was mated back with his normal mother (No. 2). This mating produced a litter of five, of which Nos. 33, 34 and 36 were abnormal and Nos. 32 and 35 were normal. Abnormal No. 3 was mated with normal No. 52 (of unrelated stock) and a litter of three normals (Nos. 53, 54, 55) resulted. Normal No. 24 (son of Nos. 1 and 2) was mated with normal No. 59 (of unrelated stock) and a litter of six normals (Nos. 58, 61, 62, 63, 64, 65) was born. Normal No. 24 was also mated with normal No. 56 (of unrelated stock) and two normals (Nos. 57 and 60) were produced.

From the abnormal strain, the eyes of eighteen females have been examined and twelve have been found to be normal. Of only five of these (Nos. 20, 33, 34, 35, 36) is the parentage known. The eyes of sixteen males from this strain have been examined and four were found to be abnormal. The parentage of ten of these (Nos. 3, 4, 5, 9, 12, 14, 22, 23, 24, 32) is known.

Since Nos. 1 and 2 were normal, the possibility is excluded that the defect is inherited as a Mendelian dominant. The abnormality occurs readily in both sexes and hence cannot be sex linked.

If we suppose that the unrelated strain does not carry the factor, and regard the character as a Mendelian recessive, we find some interesting indications in this pedigree (fig. 3). Nos. 1 and 2 must have been of such a nature, genotypically, that if *R* represent the normal and *r* the abnormal genetic factor, the constitution with respect to this character would be *Rr* for both animals. Both animals are normal, but give rise to offspring exhibiting the defect. In the offspring of Nos. 1 and 2 should be expected the ratio 3:1 (*RR*, 2*Rr*, *rr*). The actual result is six normal and four abnormal. In mating abnormal No. 3 with normal No. 2 the expectation would be a ratio of 1:1 (2*Rr*, 2*rr*). Actually, two were normal and three were abnormal in the offspring of this mating (Nos. 32, 33, 34, 35, 36). The genetic constitution of these offsprings has not been tested. In mating abnormal No. 3 with normal No. 52, heterozygous individuals would be expected without the defect. Phenotypically, Nos. 53, 54, and 55 from this mating were normal and have not been tested genetically. If the defect is of the nature of a Mendelian recessive, No. 24 must have been either *Rr* or *RR* in genetic constitution, and if mated with No. 59 (*RR*) would give either 2*RR*, 2*Rr* (all normals) or 4*RR* (all normals). The first possibility would give one half homozygous dominant and one half heterozygous, whereas the latter would give all homozygous dominant. In either case the eyes of all the offspring of such matings between Nos. 2 and 59 should be normal. This is the actual case for Nos. 58, 61, 62, 63, 64, and 65. The same chances hold for any matings between Nos. 24 and 56, which were found to be true for Nos. 57 and 60 of such a mating. To the present time, the evidence tends to show that the defect is inherited as a Mendelian recessive.

An attempt to locate a similar defect in albino rats, rabbits and guinea pigs has been made, but with negative results so far.

Here, then, is a defect in an albino strain of mice which is concerned with the total lack of definite sense cells, namely, the rods. It may be the result of degeneration, or, more probably, a suspension of development. It appears to be inherited in a very definite fashion. Embryological and histological, as well as genetical studies of this abnormality are in progress.

* This paper is a preliminary report of an investigation dealing with the inheritance of a retinal abnormality in white mice. The problem was undertaken at the suggestion of Dr. S. R. Detwiler who has offered helpful suggestions and criticisms as the work has progressed. The histological work has been done in the Zoölogical Laboratory, Harvard University, and facilities for the breeding work have been provided by the Bussey Institution. For material and suggestions, I am also indebted to Dr. H. J. Bagg, Dr. W. E. Castle, Miss E. Vicari, Miss E. Lord and Mr. H. W. Feldman.

Bagg, H. J., 1924. "The Absence of Both Kidneys Associated with Hereditary Abnormalities in Mice." *Proc. Soc. Exp. Biol. Med.*, **21**, pp. 228–229.

Bagg, H. J., and C. C. Little, 1924. "Hereditary Structural Defects in the Descendants of Mice Exposed to Roentgen Ray Irradiation." *Amer. J. Anat.*, **33**, pp. 119–145.

Castle, W. E., and C. C. Little, 1909. "The Peculiar Inheritance of Pink Eyes among Colored Mice." *Science*, **30**, pp. 313–314.

Cuénot, L., 1902. La loi de Mendel et l'hérédité de la pigmentation chez les souris. *Arch. Zoöl. Expér. Gén.*, ser. 3, **10**, Notes and Revue, pp. 27–30.

Guyer, M. F., and E. A. Smith, 1920. "Studies on Cytolysins. II. Transmission of Eye Defects." *J. Exp. Zoöl.*, **31**, pp. 171–223.

Stockard, C. R., and G. Papanicolaou, 1916. "A Further Analysis of the Hereditary Transmission of Degeneracy and Deformities by the Descendants of Alcoholized Mammals." *Amer. Nat.*, **50**, pp. 144–177.

ACTION OF DILUTE ALCOHOL ON HUMAN SUBJECTS

BY W. R. MILES

NUTRITION LABORATORY, CARNEGIE INSTITUTION OF WASHINGTON

Communicated May 26, 1924

This study on the influence of ethyl alcohol on human efficiency concerns moderate quantities and dilute solutions and is based on 166 laboratory experiments. These may be described as follows:

(1) In a series of 44 trials of which 23 were non-alcohol, a study was made of typewriting efficiency and simpler acts. Alcohol doses of 21 to 42 grams were taken in 14 to 22% (by weight) solutions. Measurements were continued for about 4 hours after ingestion and five trained typists served as subjects.

(2) Six experiments were characterized by rectal injection of the alcohol or control solution while the subject slept throughout the night in a respiration chamber. The evening and morning performances of the man were contrasted.

(3) In 70 trials with a well-trained subject, 26 of these being control, the alcohol (27.5 grams) was given in a 2.75% (by weight) solution with various dilutants. The effect was followed for 2 to 4 hours. Urine samples were collected at short intervals and the alcohol content determined.

(4) Finally, a comparison of the alcohol content of blood and urine sam-

ples was made on a group of 9 men when 27.5 grams of alcohol were taken in 27.5% and 2.75% beverages, respectively. The influence of the 2.75% solution upon physiological and psychological functions was studied and the temporal relations of the alcohol effect were compared with alcohol concentration in the urine. The alcohol was taken in one portion mixed with fruit juice and on a relatively empty stomach.

The individual experiments (each man was tested separately) were usually divided into half-hour periods. A group of measures which could be completed within this time was carried out twice (periods 1 and 2). Between periods 2 and 3 the alcohol or control solution was taken and four or more repetitions of the series of measurements followed this ingestion. Results are based on the comparison between the scores preceding and following ingestion and between the alcohol and non-alcohol groups of days. Each of the 16 men who were studied ordinarily served on 6 or more days the first two of which, unknown to the subjects, were considered as prac-

TABLE I—COMPARISON SUMMARY OF ALCOHOL EFFECTS FOR VARIOUS SERIES OF EXPERIMENTS

MEASUREMENTS	GENERAL DIRECTION OF ALCOHOL EFFECT IN FIRST 2 HOURS AFTER INGESTION	TYPEWRITING SERIES 24 GM. ALCOHOL[1]	RECTAL-FEEDING SERIES, 37.5 GM. ALCOHOL IN 7.5% SOLUTION[2]	AVE. OF 5 SERIES ON T. S., 27.5 GM. ALCOHOL IN 2.75% SOLUTION	GROUP SERIES, 27.5 GM. ALCOHOL IN 2.75% SOLUTION
		P. CT.	P. CT.	P. CT.	P. CT.
Pulse-rate during rest, rate per min...	Increased	5.3	12.0	6.0	8.8
Pulse-rate during work, rate per min..	Increased	5.6	8.2	...	...
Metabolism, oxygen consumption....	Increased	...	10.0[3]	4.2	...
Skin temperature, face.....	Increased	...	...	...	0.2[5]
Skin temperature, hands.....	Increased	...	...	...	0.7[5]
Patellar reflex, amplitude.....	Decreased	...	...	...	21.0
Lid reflex, latency.....	Slower	4.1	2.2	...	...
Lid reflex, amplitude.....	Decreased	8.8	0.0	...	...
Eye-reaction time.....	Slower	...	2.4	4.4	...
Word-reaction time.....	Slower	4.0	...	...	...
Visual acuity.....	Less keen	...	4.6	...	...
Electrical threshold sensitivity.....	Less keen	...	1.9	*1.0*[4]	...
Station, swaying of body.....	Increased	...	...	23.4	11.0
Eye-movement, velocity (adductive)..	Slower	8.3	6.1	6.5	...
Eye-movement velocity (adductive)...	Slower	5.9	2.9	5.7	...
Finger-movement speed.....	Slower	2.8	2.4	1.7	1.4
Coördination for pursuit pendulum....	Less adequate	...	...	4.7	3.2
Coördination for pursuitmeter.....	Less adequate	...	...	17.8	14.3
Typewriting, errors.....	Increased	39.3	...	...	...
Typewriting, strokes per second.....	Decreased	2.6	...	...	...
Typewriting, illegibility.....	Increased	55.0	...	...	...
Code, letters transliterated.....	Decreased	...	...	7.0	2.3

tice. Most of the subjects were occasional moderate users of alcoholic beverages. Two could be classed as habitual.

For a summary of the representative results a comparison may be made of the findings with the smaller dose (about 24 grams) in the typewriting series, the average results in the rectal-feeding series, the averages for the first five series on the trained subject, T. S., and the averages for the group of subjects who also took 2.75% alcohol. These results are assembled in Table I. The left-hand portion of the table lists the measurements used, and states the general direction of the effect of alcohol demonstrated in the first 2 hours after its ingestion.

For the pulse-rate during rest and during work, the metabolism, and the skin temperature, the alcohol effect is in the direction of increase as these factors are usually measured. Unless a specific dynamic action for alcohol be assumed, these changes, which definitely occur under the carefully controlled and routine conditions of our experiments, apparently represent a decrease in organic efficiency due to depressant action of ethyl alcohol, inasmuch as they are regularly associated with decreased reflex irritability, slower reaction, less keen, i.e., higher sensory thresholds, slower muscular movements, less adequate and accurate muscular control, and less agile mental operations. The whole qualitative picture is one of decreased human efficiency as a quickly-following result from the ingestion of this pharmacodynamic substance.

One entry (1.0% for electrical threshold) represents an improvement over normal. In one curious instance, that of the lid-reflex amplitude in the rectal-feeding series, there was no change. In former alcohol publications from the Nutrition Laboratory, reflex amplitude usually showed marked decrease after alcohol. The remaining 40 entries in the table are concordant in direction and when comparisons of the same measure may be made, as for example, eye movements or finger movements, they show fairly good quantitative agreement between the different series. There are four cases in which the change produced by alcohol is greater than 20%. These include the decrease for accuracy and quality of the typewriting performance, the decrease in amplitude of the knee-jerk, and increased swaying in the station test. In five other instances the change is from 10% to 20%. The measurements which show these prominent alcohol effects are pulse-rate during rest, metabolism, station, and coördination with the pursuitmeter. In the range from 5% to 10% there are 12 cases; between 2% and 5% 15 cases; and for changes less than 2% there are 6 entries.

The factor of accuracy or adequacy of response was more prominently influenced by alcohol than was the factor of speed. Those coördinations which made a continuous demand on the subject (station, pursuitmeter) exhibited a stronger effect than did the discontinuous type of task (reaction time, pursuit pendulum). In the typewriting investigation it was dis-

covered that with successive series of experiments on the same men, i.e., the mere repetition of the routine, the alcohol influence in multiplying errors and diminishing the legibility became more pronounced. The taking of food just before or with the alcohol caused a marked decrease in the intensity of effect.

While the concentration of alcohol in the urine was usually found to be 40% to 50% higher than that in the venous blood, still the time relations of the two curves showed such marked similarity that it appears justifiable to take the urine-alcohol results as picturing the changing alcohol content of the blood. The more dilute beverage, 2.75 as compared with 27.5% produced the lower alcohol concentration in both blood and urine, when the doses contained the same total amounts of alcohol.

The relationship of alcohol effect to the alcohol appearing in the body fluids (as represented in the urine taken at 30-minute intervals) was directly and objectively investigated probably for the first time with human subjects. It was found that the man who showed the highest average concentration also demonstrated the strongest alcohol effect, and likewise for the lowest concentration and least effect. There was a fairly parallel ranking agreement for the subjects between these extremes. Rate of absorption and body weight are obviously important factors here. The subject who was well trained in the measurements and routine demonstrated the strongest alcohol influence in the series in which his highest average urine-alcohol concentrations occurred, with fairly good agreement down to the least effect and the lowest urine content.

As the measurements were repeated every 30 minutes (in some series every 15 minutes) and the urine samples were taken as frequently, during the two to four hours after ingestion, it was likewise possible to make a comparison of the temporal changes in alcohol influence with the rise and fall of the concentration curve. The depressant symptoms increased rapidly while the alcohol content in the blood or urine was increasing and the two maxima were about synchronous, at 65 to 90 minutes after drinking but some of the symptoms decreased rather promptly after this maximal concentration, and before the alcohol content of the body fluids indicated a proportional decline.*

* The full report appears in "Alcohol and Human Efficiency," Carnegie Institution of Washington, *Publication* No. 333, 1924.

[1] The dose was about 0.5 cc. alcohol per kilogram of body-weight, hence it ranged from 21 to 28 grams of alcohol and was given in 14% to 22% solutions.

[2] In the rectal-feeding experiments the effects were measured for 6 to 8 hours after the rectal ingestion of alcohol was begun.

[3] In the 4-hour period following completed ingestion of the alcohol.

[4] Represents an improvement above normal.

[5] These results are given directly in degrees centigrade rather than in per cent.